# Calculation of Critical Means for Calendar Year 2020 RCRA Groundwater Monitoring

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

**CH2M**HILL
**Plateau Remediation Company**

**P.O. Box 1600**
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**APPROVED**
**By Sarah Harrison at 12:52 pm, Feb 20, 2020**

_____          _____
Release Approval                              Date

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# ENVIRONMENTAL CALCULATION COVER PAGE

## SECTION 1 - Completed by the Responsible Manager

| | |
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### Qualifications Summary

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Professional Licenses:

Brief Narrative of Experience: Dr. DiFilippo has extensive experience addressing the fate and transport of organic and inorganic chemicals in the environment. She has conducted numerous studies of groundwater transport, statistical geochemical analysis, groundwater age-dating, dense non-aqueous phase liquid (DNAPL) dissolution, enhanced DNAPL remediation technologies, and the use of innovative technologies for measuring in-situ concentrations of organic contaminants in sediment pore-water. At Hanford, Dr. DiFilippo has provided remediation support in the form of water-level mapping, evaluation of monitored natural attenuation (MNA) and enhanced attenuation (EA), development of methodology to asses the impact of surface water-groundwater interactions on contaminant concentrations and trends, and assessment of statistical methodologies for evaluating RCRA compliance at both interim and final status sites.

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# ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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BA, Philosophy, Haverford College, 1978
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Brief Narrative of Experience: William A. Huber, PhD, PSTAT, performs general statistical consulting with specialized capabilities in statistical sampling, environmental and spatial statistics, risk analysis, and geographic information systems. He directed the data analysis for the FCC's National Broadband Mapping Plan; was a principal reviewer of the US EPA's guidance document on statistical methods for groundwater monitoring; has testified as a statistical and mathematical modeling expert in complex federal litigation; led research and development of data visualization software; provided statistical support for hundreds of investigations of water, soils, groundwater, wastewater, and air quality; developed custom and commercial statistical software for sampling, spatial data analysis, economic estimation, and database querying; and published research in risk assessment, geostatistics, and quantum mechanics.  He has taught mathematics and statistics at St. Joseph's University, Haverford College, Penn State-Great Valley, Villanova University, and in short courses for professional organizations.  For 12 years he taught whitewater kayaking as an ACA-certified Instructor and Instructor Trainer.

Dr. Huber does business as Quantitative Decisions in Rosemont, PA and is also formally associated with Analysis & Inference in Springfield, PA and SS Papadopulos & Associates in Bethesda, MD. At A&I he supports litigation as a consulting and testifying expert.  Applications have included assessing rare risks, determining disparate impact in age and gender discrimination cases, and obtaining accurate samples of processes and populations.  At SSPA, he provides expertise in statistics and geostatistics to support environmental investigations, remediations, monitoring, and litigation.

Formerly, Dr. Huber owned a software development startup and held senior technical and management positions at a large international engineering consulting firm.  Over his career, he has helped develop small businesses and volunteer organizations, serving on their boards of directors in various positions, including as Treasurer of the Philadelphia Canoe Club, Editor of Directions Magazine (a Web publication on GIS), and Director of XI corporation (an environmental services company).  He has long been building and nurturing professional communities in GIS and statistics on the Web.  Currently he is serving as Treasurer of the Philadelphia Chapter of the American Statistical Association.

# ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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**SECTION 2 - Completed by Preparer**

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## SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

### Prior to Initiating Modeling:

**Required training for modelers completed:**
**Integration Lead:**

| N/A | | |
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| *Print First and Last Name* | *Signature* | *Date* |

**Safety Software Approved:**
**Integration Lead:**

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**Calculation Approved:**
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# Terms

| | |
|---|---|
| CM | critical mean |
| CR | critical range |
| CRAN | Comprehensive R Archive Network |
| CSV | comma-separated values (refers to an ASCII text file format) |
| CV | coefficient of variation |
| CY | calendar year |
| HEIS | Hanford Environmental Information System |
| KM | Kaplan-Meier |
| LLWMA | Low-Level Waste Management Area |
| LOQ | limit of quantitation |
| RCRA | *Resource Conservation and Recovery Act of 1976* |
| TOC | total organic carbon |
| TOX | total organic halides |
| TXT | text (refers to an ASCII text file format) |

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# 1    Purpose

This calculation derives the statistical criteria (critical means [CMs]) for indicator parameters used in *Resource Conservation and Recovery Act of 1976* (RCRA) indicator parameter evaluation and detection monitoring at interim status sites and select final status sites for calendar year (CY) 2020. The methodology for calculating the CMs was established in ECF-Hanford-13-0013, *Calculation of Critical Means for Calendar Year 2013 RCRA Groundwater Monitoring*.

# 2    Background

The Hanford Site is a U.S. Department of Energy facility located in central Washington State along the Columbia River. The site operated as a nuclear production facility starting in the 1940s, and the last reactor was decommissioned in the late 1980s. During operation, many chemicals that can potentially migrate to groundwater were used. Since decommissioning, operations at the Hanford Site have changed to demolition and restoration, including remediation of known groundwater contamination under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* and monitoring for new and existing facility impact to groundwater under RCRA. Hanford Site facilities that could create new impacts to groundwater are subject to WAC 173-303, "Dangerous Waste Regulations," which incorporate RCRA regulations for interim status (40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities") and final status (40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities").

As established in WAC 173-303-400, "Interim Status Facility Standards," the facility is required by 40 CFR 265.92(b)(3), "Sampling and Analysis," to monitor pH, specific conductance, total organic carbon (TOC), and total organic halides (TOX) as indicator parameters for groundwater contamination. These parameters are to be measured in four replicate measurements, and a composite measurement should be calculated based on the mean of these four replicates. Monitoring for these parameters is also required by WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste* (hereafter referred to as the RCRA Permit), for detection monitoring at certain final-status sites. Samples collected at downgradient wells (compliance wells) are compared to upgradient wells (background wells) to identify potential impacts to groundwater from the facility. If concentrations in the compliance wells are significantly different from CM concentrations in background wells, there is evidence of facility impact to groundwater.

CMs are calculated for the 12 RCRA sites listed in Table 1 for indicator parameter comparisons under indicator evaluation monitoring. This document describes the approach for calculating CMs for statistical comparisons. The calculated CMs will be compared with data collected during CY 2020 to determine if any exceedances (compliance well concentrations higher than the calculated CMs) have occurred. These comparisons will occur in RCRA monitoring reports and are beyond the scope of this document. CMs are calculated once for each CY unless sampling changes warrant recalculation.

Table 1. RCRA Sites for Indicator Parameter Statistical Comparisons

| RCRA Site | Operable Unit |
|---|---|
| 216-A-29 Ditch | 200-PO-1 |
| 216-A-36B Crib | 200-PO-1 |

Table 1. RCRA Sites for Indicator Parameter Statistical Comparisons

| RCRA Site | Operable Unit |
|---|---|
| 216-A-37-1 Crib | 200-PO-1 |
| 216-B-3 Pond | 200-PO-1 |
| 216-B-63 Ditch | 200-BP-5 |
| 216-S-10 Pond and Ditch | 200-UP-1 |
| Low-Level Waste Management Area-1 (LLWMA-1) | 200-BP-5 |
| Low-Level Waste Management Area-2 (LLWMA-2) | 200-BP-5 |
| Low-Level Waste Management Area-3 (LLWMA-3) | 200-ZP-1 |
| Low-Level Waste Management Area-4 (LLWMA-4) | 200-ZP-1 |
| 600 NRDWL Sanitary Landfill | 200-PO-1 |
| WMA A-AX | 200-PO-1 |

Reference: *Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq.

LLWMA  =  Low-Level Waste Management Area

NRDWL  =  nonradioactive dangerous waste landfill

RCRA  =  *Resource Conservation and Recovery Act of 1976*

WMA  =  waste management area

## 2.1   Derivation of and Calculation of Critical Means as Prediction Limits

As established in WAC 173-303-400, the facility is required by 40 CFR 265.92(b)(3) to monitor pH, specific conductance, TOC, and TOX as indicator parameters for groundwater contamination. At each sampling event, these parameters are usually measured in four replicate samples. Replicate measurements are combined into a single numerical result, called a *composite measurement* (of which each replicate is one *aliquot*). The composite value is the arithmetic mean of the aliquot values, after first setting the value of any nondetect to its reporting limit. When all the aliquots are nondetects, their composite is considered a nondetect and its reporting limit is set to the smallest reporting limit of the aliquots.

All statistical procedures are carried out separately for each RCRA unit and analyte. The unit-wide false-positive rate is controlled at $\alpha = 1\%$ by means of a Bonferroni adjustment based on the number of compliance decisions anticipated during each monitoring event to which these procedures will apply.

A set of reference (background) data is created for each analyte at each RCRA unit. In most cases, these data are obtained at designated upgradient wells during a specified (recent) period. The reference data, which consist of replicate samples obtained at each well during each sampling event, are composited into one value per well per sampling event. This background dataset is used to compute CMs (or for pH, a critical range [CR]). These are prediction limits (or intervals, respectively) for data that will be obtained at downgradient (compliance) wells during any single monitoring event. Composite measurements from those downgradient wells will be compared to CMs and CRs. Any downgradient composite result that exceeds its CMs (or lies outside its CRs, in the case of pH) will be considered statistically significant evidence that the groundwater it represents differs from conditions represented by the reference dataset. Such a determination is called a positive result.

CMs and CRs are derived from the test statistic for the Average Replicate t-test and calculated using the following formulas:

Critical mean $$CM = m + t_{df,k,\alpha}\, s \sqrt{1 + \frac{1}{n}}$$ **(Eq. 2.1)**

Critical range $$CR = m \pm t_{df,k,\alpha/2}\, s \sqrt{1 + \frac{1}{n}}$$ **(Eq. 2.2)**

where:

$m$      = estimates the background mean

$s$      = estimates the background standard deviation

$n$      = the count of data used to compute the mean m

$\alpha$      = the minimum unit-wide false-positive rate for any single (future) monitoring event; set at 1%

$k$      = the number of comparisons (counting all analytes) that have the potential to create a positive result within a RCRA unit during any single monitoring event

$t_{df,k,\alpha}$      = the upper 100% – $\alpha$/k quantile of Student's t distribution with df degrees of freedom

$t_{df,k,\alpha/2}$      = the upper 100% – $\alpha$/(2k) quantile of Student's t distribution with df degrees of freedom

$df$      = the degrees of freedom (equal to $n – 1$ for the interwell tests).

The Student $t$ quantiles have been generically referred to as "$t_{crit}$". The quantities $\alpha/k$ and $\alpha/(2k)$ have been referred to as the "adjusted" $\alpha$ or $\alpha_{adjusted.}$. These terms are used in the tabulated results appearing in Chapter 7. The Student $t$-test was used in accordance with 40 CFR 265.93, "Preparation, Evaluation, and Response."

Typically, $k$ will equal the number of upgradient and downgradient wells multiplied by the number of analytical parameters being tested (always equal to 4).

According to ECF-Hanford-13-0013, CMs (and CRs) are recalculated annually or if the number of comparisons changes. Annual recalculation, using a sliding period for selecting the background data, is intended to account for changing background conditions as provided in Section 5.3.5.3 of the *Statistical Guidance for Ecology Site Managers* (Washington State Depart of Ecology publication number 92-54). Changes in the number of comparisons are usually the result of changes in monitoring well networks (i.e., wells are added or deleted). If changes occur in a monitoring well network, CMs and CRs for that facility are recalculated for subsequent sampling events using the new well network.

## 2.2 Counting Comparisons for the Bonferroni Adjustment

For comparability with previous calculations, as set forth in ECF-Hanford-13-0013, the number of comparisons for this analysis includes both upgradient and downgradient wells. Under 40 CFR 265.93(b), the comparison must consider individually each of the wells in the monitoring system. As such, at each RCRA unit, the number of analytes is multiplied by the total number of wells, including background wells, to accommodate planned testing of future results at upgradient wells.

# 3  Methodology

CMs were calculated using the interwell approach following procedures outlined in EPA 530/R-09-007, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, to set limits based on data from an upgradient well that is assumed to be unimpacted by activities at the monitored site.

## 3.1  Background and Compliance Wells

At each RCRA site, background wells are identified as wells that were hydraulically upgradient of the facility. Compliance wells are identified as wells that were hydraulically downgradient of the facility. A list of wells and well locations based on RCRA sites is presented in Appendix A.

## 3.2  Data Acquisition

Groundwater chemistry data are downloaded from the Hanford Environmental Information System (HEIS), which is maintained by CH2M HILL Plateau Remediation Company, and exported into a Microsoft$^®$ Access$^®$ database (HEIS_Chem1_01152020.accdb and HEIS_Chem2_01152020.accdb). Data for this analysis were downloaded from the HEIS database on January 15, 2020. The HEIS database contains one table (HEIS2_ADM_PNLGW_STD_RESULT_MV_1 and HEIS2_ADM_PNLGW_STD_RESULT_MV_2, respectively), which contains information on groundwater chemistry samples, including lab and review data qualifiers, sample medium, sample collection purpose, analytical method, and reporting limits. Fields extracted from the HEIS database for use in the CM calculations are presented in Table 2.

The RCRA parameter data (pH, specific conductance, TOC, and TOX) from the HEIS database are exported into two text (TXT) files named qryChemHeis1.txt and qryChemHeis2.txt.

Table 2. HEIS Database Fields

| Field Extracted | Definition |
|---|---|
| WELL_NAME | Location ID |
| SAMP_DATE_TIME | Sampling Date |
| STD_CON_LONG_NAME | Analyte Name |
| STD_VALUE_RPTD | Reported Concentration |
| STD_ANAL_UNITS_RPTD | Units for Concentration Measurement |
| LAB_QUALIFIER | Lab Data Qualifier |
| REVIEW_QUALIFIER | Review Data Qualifier [a] |
| COLLECTION_PURPOSE | Primary Reason for Sample Collection [b] |

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$^®$ Microsoft and Access are registered trademarks of Microsoft Corporation in the United States and other countries.

Table 2. HEIS Database Fields

| Field Extracted | Definition |
|---|---|
| VALIDATION_QUALIFIER | Validation Qualifier |

a. Review Data Qualifier codes are as follows:

F = The result is undergoing further review.

G = Record has been reviewed and determined to be correct, or the record has been modified to make it correct.

H = Laboratory holding time exceeded before the sample was analyzed.

P = Potential problem. Collection/analysis circumstances make value questionable.

Q = Associated quality control sample is out of limits.

R = Do not use. Further review indicates the result is not valid. These points are not included in outputs or downloads.

Y = Result suspect. Review – insufficient evidence to show result valid or invalid.

Z = Miscellaneous circumstances exist. Additional information may be found in the RESULT_COMMENT field for this record.

b. Sample collection purpose codes are as follows:

| | | | | |
|---|---|---|---|---|
| C | = Characterization | T | = | Transportation |
| IH | = Industrial Hygiene | TS | = | Time Series |
| IP | = In Process | VER | = | Verification |
| R | = Routine | VP | = | Vertical Profile |
| S | = Special Studies | WM | = | Waste Management |

## 3.3  Review Qualifiers

Data are removed from the dataset prior to calculation of CMs based on their review qualifiers (Table 3). This step was conducted for each individual sample prior to compiling composite samples.

Table 3. Review Qualifiers for Data Removal

| Review Qualifier | Definition |
|---|---|
| Y | Result is suspect. Review had insufficient evidence to show result valid or invalid. |
| R | Do not use. Further review indicates the result is not valid. |

## 3.4  Collection Purpose

Data for the calculation of CMs are limited to data that were collected for routine purposes or verification (i.e., COLLECTION_PURPOSE = "R" or "VER"). This step was conducted for each individual sample prior to compiling composite samples.

## 3.5  Outliers

Based on visual inspection of the data, obvious outliers were removed prior to analysis (Table 4). The removal of this outlier is consistent with previous years' calculations (ECF-Hanford-18-0004, *Calculation of Critical Means for Calendar Year 2018 RCRA Groundwater Monitoring*). Additional

outlier testing was performed on composite samples (see Section 3.11) to identify any other potential outliers.

Table 4. Outliers Removed from Analysis

| Well | Contaminant of Concern | Sample Date | Basis |
|---|---|---|---|
| 699-26-38 | Total organic carbon | 10/17/2016 | An order of magnitude higher than all other measured concentrations at this location |

## 3.6   Calculation of Composite Results

At each RCRA site and for each well and analyte, composite results are calculated as the average of the replicates (its *aliquot* measurements). When none of the aliquots in the composite (also referred to as a "composite sample" to emphasize the composite nature of the measurements) are classified as a nondetect, the following statistics are calculated to characterize the background conditions and to support the CM/CR calculations (in Equations 2.1 and 2.2, respectively):

Estimated background mean for composite sample

$$m_c = \frac{1}{n_c} \sum_{i=1}^{n_c} x_i \qquad \textbf{(Eq. 3.1)}$$

Estimated standard deviation for composite sample

$$s_c = \sqrt{\frac{1}{n_c - 1} \sum_{i=1}^{n_c} (x_i - m_c)^2} \qquad \textbf{(Eq. 3.2)}$$

where:

$m_c$ = the composite sample mean

$n_c$ = the number of aliquots in the composite sample

$x_i$ = the aliquot measurement

$s_c$ = the composite sample standard deviation.

When one or more values in the dataset are nondetects, the procedures described in Section 3.9.2 (treatment of nondetects for computing statistics of reference datasets) are used to compute $m_c$ and $s_c$.

## 3.7   Identifying Background Data

CMs for each RCRA site are calculated from measurements at wells identified as being upgradient of the RCRA site (i.e., background wells). Classification of well location (upgradient versus downgradient) is presented in Appendix A. Changes to groundwater remedies may likely change groundwater flow at the 216-B-63 Ditch and Low-Level Waste Management Area (LLWMA)-2 RCRA sites. Table 5 presents the current background well networks identified in the groundwater monitoring plans and proposed background wells based on evaluation of groundwater flow changes from ongoing groundwater remedies. CMs are calculated for both the current well network and proposed changes. For LLWMA-1, no changes were made to the background well network, however, changes were made to the compliance well portion

of the network. This resulted a change in the number of comparisons and, consequently, a change in the calculated critical means. For all remaining RCRA areas, no changes were made to the well networks.

Table 5. RCRA Areas with Multiple Calculated CMs/CRs

| RCRA Area | Network | Background Wells |
|---|---|---|
| 216-B-63 Ditch | Current | 299-E33-33<br>299-E34-12<br>299-E34-8 |
| | Proposed | 299-E33-33 |
| LLWMA-2 | Current | 299-E27-10 |
| | Proposed | 299-E34-2 |

LLWMA  =  low level waste management area

## 3.8   Determination of Date Range

EPA 530/R-09-007 (pg. 5-3) recommends at least "8 to 10 independent background observations be collected before running most statistical tests." To ensure this, the number of composite measurements for each analyte at each RCRA site is counted over a minimum 3-year period covering 2017 and 2019 and adjusted, as necessary, to provide an adequate background dataset. Whenever this count is less than eight for any analyte at a RCRA site, the date range is expanded backwards in time until all analytes have at least eight samples. This common date range is used to estimate background conditions for the CR/CM calculations at that site. If the number of detected values within the date range for TOC or TOX was less than 2, earlier data was added for that indicator parameter so that there was a minimum of 2 nondetects in the dataset. The starting dates for each RCRA site and analyte are presented in Table A-2.

## 3.9   Handling Nondetects

Processing of nondetects proceeds through two stages. In the first stage, raw data are combined into composite measurements. Each composite is flagged according to the detectability of the data contributing to its value. These composites are grouped into reference datasets for each analyte at each RCRA unit. At the second stage, estimates of the means (*m*) and standard deviations (*s*) required for the CM/CR calculations are computed, depending on what proportion of the reference dataset consists of nondetects.

### 3.9.1   Stage 1: Computing Composite Values

All decisions in this monitoring program are based on composite measurements. That is, when four measurements are available at one monitoring event for an analyte at a well, these measurements are called replicates and are combined into a single value called a composite measurement for that event-analyte-well combination. The replicate measurements become the aliquots of the resulting composite measurement.

At the outset, beginning with the data selected as described in Sections 3.2 through 3.8, the following summary statistics are computed for each composite, *c*. The individual aliquot values are denoted $x_i$ with

indexes ranging from 1 through $n_c$. When replicate $i$ is not detected, $x_i$ equals the reporting limit associated with that sample.

| | | |
|---|---|---|
| Number of nondetects | $n_{c,0}$ | **(Eq. 3.3)** |
| Proportion of nondetects | $\dfrac{n_{c,0}}{n_c}$ | **(Eq. 3.4)** |
| Minimum detection limit[1] | $\min\,(x_i \mid \text{result } i \text{ not detected})$ | **(Eq. 3.5)** |
| Maximum detected value[2] | $\max(x_i)$ | **(Eq. 3.6)** |
| Mean of all values | $m_c = \dfrac{1}{n_c}\sum_{i=1}^{n_c} x_i$ | **(Eq. 3.7)** |
| Coefficient of variation (CV) (calculated when all aliquots of a composite sample are detected values) | $\dfrac{s_{c,d}}{m_{c,d}}$ | **(Eq. 3.8)** |

where:

$s_{c,d}$ = the standard deviation of the composite sample when all aliquots are detected (i.e., no nondetects)

$m_{c,d}$ = the mean of the composite sample when all aliquots are detected (i.e., no nondetects).

The composite measurement is taken to be the mean of all values ($m_c$), and the composite measurement standard deviation is $s_c$. Multiple reporting limits were not present for composite sample aliquots (i.e., all aliquots of any composite sample had the same reporting limit).

The reporting limit is substituted for aliquots with measurements below the reporting limit. When all of the aliquots are nondetects, the sample is treated as a nondetect in the subsequent analysis and its reporting limit is set to the smallest of the aliquot reporting limits. If the proportion of the nondetects is less than 1, the composite measurement is treated as a detected value in the subsequent analysis.

### 3.9.2 Stage 2: Treatment of Nondetects for Computing Statistics of Reference Datasets

#### 3.9.2.1 Datasets with Less Than 10 Percent Nondetects

EPA 530/R-09-007 (pg. 15-5) indicates that t-tests and prediction limits (and therefore the CM/CR calculations that are derived from them) are not significantly affected by substitution of half the reporting limit when the proportion of nondetects is no more than 10 percent to 15 percent of the total sample. Therefore, this substitution method is employed here for datasets where up to 10 percent of the composite samples are identified as nondetects. Equations 3.1 and 3.2 are then applied as if all values were actually quantified.

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[1] Defined as detection limit in ECF-Hanford-13-0013, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*.

[2] When all aliquots of a composite sample are nondetects, the maximum detected value is equal to the maximum reporting limit.

### 3.9.2.2   Datasets with Greater than 10 Percent Nondetects

The Kaplan-Meier (KM) estimator is used to account for nondetects in datasets where more than 10 percent of the composite measurements are identified as nondetects. The KM method is a nonparametric approach that uses a ranked ordering method to estimate the proportion of concentrations below each reporting limit. EPA 530/R-09-007 provides a detailed description of the KM method (pg. 15-7). The calculations are carried out using the EnvStats package in R (see Chapter 5 of this document). These calculations produce estimates of the background mean and standard deviation, replacing those in Equations 3.1 and 3.2.

## 3.10  Test for Normality

The background datasets are tested at the $\alpha = 0.05$ level using the Shapiro-Wilk test to evaluate the null hypothesis that the data are normally distributed. EPA 530/R-09-007 (pg. 10-13) provides a detailed description of the Shapiro-Wilk test. It is conducted using the "stats" package in R (see Chapter 5 of this document). CMs and CRs calculated from datasets that show evidence of departing from normal distributions are flagged in the tabulated results presented in Chapter 7. The Shapiro-Wilk test was also used to evaluate the null hypothesis that the data are log-normally distributed.

## 3.11  Test for Outliers

The background datasets are tested using the Grubbs test at the $\alpha = 0.001$ level to identify outliers, consistent with ECF-Hanford-13-0013. This test is useful for identifying exactly one outlier in a dataset (Grubbs, 1969, "Procedures for Detecting Outlying Observations in Samples") using composite measurements. The Grubbs test is conducted using the "outliers" package in R (see Chapter 5 of this document). Outliers were removed at the discretion of project scientists. No additional outliers to those listed in Table 4 were removed for the CY 2020 CM calculations based on the Grubbs test results.

## 3.12  Intrawell Method

Following the procedures set forth in ECF-Hanford-18-0004, an intrawell test was used for the LLWMA-2 and LLWMA-3 sites. The LLWMA-3 background and compliance monitoring wells may be affected by injection of treated effluent from the 200 West Pump and Treat, which is injected downgradient of the background well used for establishing background at LLWMA-3.

For upgradient-to-downgradient well comparisons, a crucial assumption is that significant changes in downgradient well groundwater quality are only caused by onsite releases of regulated constituents. The injection of treated effluent results in spatial variability, potentially leading to large numbers of false-positive detections at the compliance wells based on CMs calculated by the interwell method. Intrawell testing is identified in EPA 530/R-09-007 as a method to eliminate the problem of natural spatial variability.

Water level mapping and particle-tracking simulations described in a draft engineering evaluation report for low-level burial ground Trench 94 (in process) indicate the LLWMA-2 upgradient monitoring well is not upgradient, but is cross-gradient. Upgradient wells are not feasible due to the basalt outcropping above the water table upgradient of the site. For LLWMA-2, intrawell testing may therefore provide more accurate baseline for use in statistical comparisons[3].

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[3] In the calculations, well 299-E34-2 is identified as an upgradient well.

Interim status monitoring regulations applicable to LLWMA-2 and LLWMA-3 do not provide for intrawell testing; however, CMs are calculated using the intrawell method and provided for comparison to interwell CMs in Chapter 7.

Intrawell limit methods use previous results collected in a monitoring well to set a limit that determines whether future samples in the same well represent an adverse change in groundwater quality. A future result above its limit (or, in the case of pH, outside its lower and upper limits) is considered a statistically significant ("positive") and will be interpreted as evidence of a real difference between the previous results and the future measurement.

The initial steps for obtaining and subsetting data for the intrawell method are the same as described in Sections 3.2. through 3.8. The method for handling nondetects and assessing normality in the intrawell method are the same as described in Sections 3.9 and 3.10. Calculations specific to the intrawell method are described in the following subsections.

The wells evaluated using the intrawell test are presented in Table 6.

Table 6. RCRA Sites and Wells Evaluated Using the Intrawell Test

| RCRA Area | Wells |
|---|---|
| Low-Level Waste Management Area 2 (LLWMA-2) | 299-E27-8<br>299-E27-9<br>299-E27-10<br>299-E27-11<br>299-E27-17<br>299-E34-2<br>299-E34-9<br>299-E34-10<br>299-E34-12 |
| Low-Level Waste Management Area 3 (LLWMA-3) | 299-W9-2<br>299-W10-29<br>299-W10-30<br>299-W10-31 |

LLWMA = low level waste management area
RCRA = *Resource Conservation and Recovery Act of 1976*

### 3.12.1 Calculation of Test Statistics and Critical Means

As established in ECF-HANFORD-13-0013, Rev.1, the CM should be calculated as in Equations 2.1 and 2.2, but based on a pooled standard deviation ($s_{ij}$) estimated from all the compliance wells in the RCRA unit. The wells, which will be indexed by $j = 1, 2, 3$, contribute three reference datasets ($x_{ij}$) where $j$ (which indexes the individual composite results) ranges from 1 through $n_j$ (the amount of reference data available at each well). The total count of reference data is written $n$. For specific conductance, TOC, and TOX, let $y_{ij} = \ln(x_{ij})$ and for pH, let $y_{ij} = x_{ij}$. Let $n_w$ be the number of wells in the pooled dataset (in this case, 3).

Individual well log means

$$m_j = \frac{1}{n_j} \sum_{i=1}^{n_j} y_{ij}$$

**(Eq. 3.9)**

| Individual well log variance | $$s_j^2 = \frac{1}{n_j - 1} \sum_{i=1}^{n_j} \left( y_{ij} - m_j \right)^2$$ | **(Eq. 3.10)** |

| Pooled log variance | $$s^2 = \frac{1}{\sum_{j=1}^{n_w}(n_j-1)} \sum_{j=1}^{n_w}(n_j - 1)\, s_j^2 = \frac{1}{n-3} \sum_{j=1}^{n-3}(n_j - 1)s_j^2$$ | **(Eq. 3.11)** |

| Pooled well standard deviation | $$s = \sqrt{s^2}$$ | **(Eq. 3.12)** |

| Pooled degrees of freedom | $$df_{pooled} = n - n_w$$ | **(Eq. 3.13)** |

| Individual well critical means | $$CM_j = \exp\left( m_j + t_{df_{pooled},k,\alpha}\, s\sqrt{1 + \frac{1}{n_j}} \right)$$ | **(Eq. 3.14)** |

| Individual well critical range | $$CM_j = m_j \pm t_{df_{pooled},k,\alpha}\, s\sqrt{1 + \frac{1}{n_j}}$$ | **(Eq. 3.15)** |

The value of $k$ is set, as in all other cases, to the total number of analytes (four).

Each intrawell dataset was evaluated to determine if the pooled standard deviation approach was appropriate. Datasets were evaluated for temporal trends and spread using timeseries plots and violin plots of median absolute deviation and range in standard deviation. A summary of the pooled standard deviation evaluation is presented in Table 7.

Table 7. Summary of Pooled Standard Deviation Evaluation

| RCRA Area | Analyte | Use Pooled Standard Deviation? | Basis |
|---|---|---|---|
| Low-Level Waste Management Area 2 (LLWMA-2) | pH | Yes | |
| Low-Level Waste Management Area 2 (LLWMA-2) | Specific conductance | No | Several wells display temporal trends and spatial variability among wells [a,b] |
| Low-Level Waste Management Area 2 (LLWMA-2) | Total organic carbon | No | Majority of wells have > 50% nondetects |
| Low-Level Waste Management Area 2 (LLWMA-2) | Total organic halides | No | Spatial variability among wells [b] |
| Low-Level Waste Management Area 3 (LLWMA-3) | pH | Yes | |

Table 7. Summary of Pooled Standard Deviation Evaluation

| RCRA Area | Analyte | Use Pooled Standard Deviation? | Basis |
|---|---|---|---|
| Low-Level Waste Management Area 3 (LLWMA-3) | Specific conductance | Yes | |
| Low-Level Waste Management Area 3 (LLWMA-3) | Total organic carbon | No | Spatial variability among wells [b] |
| Low-Level Waste Management Area 3 (LLWMA-3) | Total organic halides | No | Several wells display temporal trends [a] |

a. Based on visual inspection of timeseries plots.

b. Spatial variability was identified for a site if the range in standard deviation was greater than 3.

LLWMA  =  low level waste management area

RCRA  =  *Resource Conservation and Recovery Act of 1976*

# 4   Assumptions and Inputs

The following assumptions are made in the CMs analysis:

1.  Reference data from upgradient wells are assumed to represent natural groundwater or background conditions.

2.  Unless otherwise noted, it is assumed that the mean and variance of each analytical parameter exhibit no spatial variation within each region represented by the upgradient wells at any RCRA unit.

3.  Time series of results are assumed stationary, which implies they have no trend. While it is recognized that groundwater quality may naturally change with time, accounting for trends is deliberately avoided by choosing a relative short period of records and periodically recalculating CMs.

4.  The Student's t-test, from which the CM and CR limits are derived, assumes the sampling distribution of the mean follows a normal distribution and the sampling distribution of the variance independently is proportional to a chi-squared distribution with the assumed degrees of freedom. A large coefficient of variation (CV) can be an indication of non-normality of the mean (Equation 3.8). As a diagnostic adjunct to the Shapiro-Wilk test of normality, the CV is calculated each time a CM is calculated.

5.  It is assumed that no seasonal fluctuations occur in the data.

6.  Typically, datasets with large percentages of nondetects (i.e., greater than 50%) will result in CMs close to the detection limits but less than quantitation limits (which are approximately three times the detection limits). When the CM is below the limit of quantitation (LOQ), the LOQ is also used as a comparison value for detecting facility effects. LOQ calculations and comparisons are made elsewhere.

Table 8 summarizes the number of data used in the calculation of CMs/CRs, including the number of data removed by each data processing step.

Table 8. Summary of Data used for Calculation of CMs/CRs

| | Number of Samples | Percent of Total |
|---|---|---|
| **Number of Total Aliquots from HEIS Database** | | |
| **Total Number of Data from HEIS** | **159,176** | |
| pH | 62,804 | 39% |
| Specific conductance | 62,807 | 39% |
| TOC | 18,273 | 11% |
| TOX | 15,292 | 10% |
| **Number of Total Aliquots for Upgradient Wells** | | |
| **Total Number of Data for Upgradient Wells** | **13,286** | |
| pH | 3,468 | 26% |
| Specific conductance | 3,471 | 26% |
| TOC | 3,361 | 25% |
| TOX | 2,986 | 22% |
| **Number of Aliquots Removed Based on Review Qualifiers** | **123** | **0.94%** |
| pH | 0 | 0.00% |
| Specific conductance | 1 | 0.03% |
| TOC | 86 | 2.56% |
| TOX | 36 | 1.21% |
| **Number of Aliquots Removed Based on Collection Purpose** | **10** | **0.08%** |
| pH | 1 | 0.03% |
| Specific conductance | 1 | 0.03% |
| TOC | 8 | 0.24% |
| TOX | 0 | 0.00% |
| **Number of Aliquots** | **13,153** | **99%** |
| **Number of Nondetects** | **3,251** | **25%** |
| pH | 0 | 0.0% |
| Specific conductance | 0 | 0.0% |
| TOC | 1,402 | 42% |

Table 8. Summary of Data used for Calculation of CMs/CRs

|  | Number of Samples | Percent of Total |
|---|---|---|
| TOX | 1,849 | 62% |
| **Number of Composite Measurements for Upgradient Wells** | | |
| **Number of Event-Analyte-Well Combinations** | **3,283** | |
| pH | 941 | 27% |
| Specific conductance | 939 | 27% |
| TOC | 768 | 23% |
| TOX | 635 | 21% |

HEIS    =    Hanford Environmental Information System

TOC    =    total organic carbon

TOX    =    total organic halides

# 5    Software Applications

CMs were calculated using the public domain computing platform R (version 3.4.3 published 11/30/2017). R provides data manipulation, calculation, and graphical display capabilities to support data analysis (Venables et al., 2015, *An Introduction to R Notes on R: A Programming Environment for Data Analysis and Graphics*). It is freely available to the public and can be compiled and run on a variety of platforms (UNIX, Windows, and Mac OS). The base installation of R contains statistical and plotting functions and many more are available for download through the Comprehensive R Archive Network (CRAN). Several R packages are used for calculating CMs. The packages were downloaded from the CRAN and are listed in Table 9.

Table 9. R Packages Used for Critical Means Calculations

| [R] Package | Package Description | Version |
|---|---|---|
| data.table | Enhanced data processing | 1.10.4-3 |
| EnvStats | Package for Environmental Statistics, Including US EPA Guidance | 2.3.0 |
| lawstat | Tools for biostatistics, public policy, and law | 3.2 |
| outliers | Tests for outliers | 0.14 |
| plyr | Tools for splitting, applying, and combining data | 1.8.4 |
| reshape2 | Restructure and aggregate data | 1.4.3 |

US EPA = U.S. Environmental Protection Agency

# 6   Calculation

The R code used to process the data and calculate CMs for each site is included in Appendix B. The text files (qryChemHeis1.txt and qryChemHeis2.txt) contain the data downloaded from the HEIS database (see Section 3.2), and the comma-separated values (csv) file (ClosureSamples_01302017.csv) contains the list of closure samples to be excluded from the analysis. In addition, a Microsoft Excel® file (RCRA_Wells_for_2020_CM_Calcs.xlsx) containing information on well location for each RCRA site and the start dates for analysis are used in the R code.

Output information is written to the files:

1. HANFORD-CRITICAL_MEANS-INTERWELL_2020-(date of analysis).csv – Contains CMs calculated using the Interwell Method

2. HANFORD-CRITICAL_MEANS-INTRAWELL_2020-(date of analysis).csv – Contains CMs for LLWMA-2 and LLWMA-3 calculated using the Intrawell Method

3. DataSummary_ALLHEISSamples_(date of analysis).csv – Contains all of the data removed based on review qualifiers

4. DataSummary_AllUpgradient_(date of analysis). csv – Contains a summary of the total number of samples for upgradient wells

5. Totals_Removed_Qualifier_(date of analysis). csv – Contains a summary of the total number of samples removed based on the review qualifier

6. Totals_Removed_Collection_(date of analysis). csv – Contains a summary of the total number of samples removed based on the collection purpose

7. Totals_Aliquots-(date of analysis). csv – Contains a summary of the total number of aliquots in the final dataset

8. Totals_NDs-(date of analysis). csv – Contains a summary of the total number of nondetects in the final dataset

9. Totals_Composite-(date of analysis). csv – Contains a summary of the total number of composite samples in the final dataset

This information has been formatted to produce the tables presented in the results section of this report as well as in the annual groundwater monitoring report.

# 7   Results

Results are listed in Tables 10 through 26.

Table 10. Critical Means for the 216-A-29 Ditch for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 4 | | | |
| Date Range for Data | 1/16/2018 – 10/8/2019 | | | |
| Number of Composite Samples | 33 | 32 | 33 | 33 |
| % Nondetects | 0% | 56% | 55% | 0% |
| Mean | 400 µS/cm | 348 µg/L | 4.00 µg/L | 8.22 su |
| Median | 405 µS/cm | 330 µg/L | 3.93 µg/L | 8.23 su |
| Standard Deviation | 115 µS/cm | 53.4 µg/L | 0.992 µg/L | 0.114 su |
| Coefficient of Variation | 0.287 | 0.154 | 0.248 | 0.0138 |
| Maximum | 571 µS/cm | 505 µg/L | 7.80 µg/L | 8.51 su |
| Number of Comparisons | 32 | 32 | 32 | 32 |
| alpha per comp ($\alpha_{adjusted}$) | 3.13E-04 | 3.13E-04 | 3.13E-04 | 1.56E-04 |
| $t_{crit,i}$ | 3.79 | 3.81 | 3.79 | 4.04 |
| Critical Mean | 842[a,b] µS/cm | 554 [a,b] µg/L | 7.82 [a,b] µg/L | 8.68 su |
| Lower Critical Range | | | | 7.75 su |

a. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

b. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

µS/cm =   micro-Siemens per centimeter

µg/L   =   micrograms per liter

su      =   standard unit

Table 11. Critical Means for the 216-A-36B Ditch for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 2 | | | |
| Date Range for Data | 7/8/2016 – 7/16/2019 | | | |
| Number of Composite Samples | 21 | 19 | 19 | 21 |
| % Nondetects | 0% | 47% | 32% | 0% |
| Mean | 658 µS/cm | 327 µg/L | 4.63 µg/L | 7.83 su |
| Median | 669 µS/cm | 330 µg/L | 3.66 µg/L | 7.87 su |
| Standard Deviation | 65.1 µS/cm | 213 µg/L | 2.82 µg/L | 0.231 su |
| Coefficient of Variation | 0.0989 | 0.65 | 0.608 | 0.0296 |
| Maximum | 773 µS/cm | 1,110 µg/L | 15.7 µg/L | 8.16 su |
| Number of Comparisons | 24 | 24 | 24 | 24 |
| alpha per comp ($\alpha_{adjusted}$) | 4.17E-04 | 4.17E-04 | 4.17E-04 | 2.08E-04 |
| $t_{crit,i}$ | 3.93 | 4.00 | 4.00 | 4.22 |
| Critical Mean | 920 µS/cm | 1,200[a,b] µg/L | 16.2[a,b] µg/L | 8.83[a,b] su |
| Lower Critical Range | | | | 6.83[a,b] su |

a. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

b. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

µS/cm = micro-Siemens per centimeter

µg/L = micrograms per liter

su = standard unit

Table 12. Critical Means for the 216-A-37-1 Crib for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 2 | | | |
| Date Range for Data | 1/7/2016 – 10/4/2019 | | | |
| Number of Composite Samples | 29 | 29 | 29 | 29 |
| % Nondetects | 0% | 31% | 52% | 0% |
| Mean | 478 µS/cm | 355 µg/L | 4.49 µg/L | 8.28 su |
| Median | 504 µS/cm | 339 µg/L | 3.93 µg/L | 8.24 su |
| Standard Deviation | 56.1 µS/cm | 78.4 µg/L | 2.05 µg/L | 0.152 su |
| Coefficient of Variation | 0.117 | 0.221 | 0.457 | 0.0183 |
| Maximum | 545 µS/cm | 545 µg/L | 10.4 µg/L | 8.75 su |
| Number of Comparisons | 24 | 24 | 24 | 24 |
| alpha per comp ($\alpha_{adjusted}$) | 4.17E-04 | 4.17E-04 | 4.17E-04 | 2.08E-04 |
| $t_{crit,i}$ | 3.74 | 3.74 | 3.74 | 4.00 |
| Critical Mean | 692[a,b] µS/cm | 654 [a,b] µg/L | 12.3 [a,b] µg/L | 8.90 su |
| Lower Critical Range | | | | 7.67 su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

µS/cm  = micro-Siemens per centimeter

µg/L   = micrograms per liter

su     = standard unit

Table 13. Critical Means for the 216-B-3 Pond for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 3 | | | |
| Date Range for Data | 9/29/2015 – 7/1/2019 | | | |
| Number of Composite Samples | 27 | 24 | 23 | 27 |
| % Nondetects | 0% | 25% | 70% | 0% |
| Mean | 299 µS/cm | 423 µg/L | 3.93 µg/L | 8.05 su |
| Median | 280 µS/cm | 395 µg/L | <3.33[a] µg/L | 8.04 su |
| Standard Deviation | 37.5 µS/cm | 189 µg/L | 1.13 µg/L | 0.14 su |
| Coefficient of Variation | 0.125 | 0.448 | 0.287 | 0.0174 |
| Maximum | 367 µS/cm | 1,110 µg/L | 7.80 µg/L | 8.25 su |
| Number of Comparisons | 20 | 20 | 20 | 20 |
| alpha per comp ($\alpha_{adjusted}$) | 5.00E-04 | 5.00E-04 | 5.00E-04 | 2.50E-04 |
| $t_{crit,i}$ | 3.71 | 3.77 | 3.79 | 3.97 |
| Critical Mean | 441[b,c] µS/cm | 1,150[b,c] µg/L | 8.31[b,c,d] µg/L | 8.61[b,c] su |
| Lower Critical Range | | | | 7.48[b,c] su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

c. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

d. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

µS/cm  =  micro-Siemens per centimeter

µg/L  =  micrograms per liter

CM  =  critical mean

LOQ  =  limit of quantitation

su  =  standard unit

Table 14. Critical Means for the 216-B-63 Ditch for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 3 | | | |
| Date Range for Data | 4/1/2016 – 11/6/2019 | | | |
| Number of Composite Samples | 26 | 25 | 25 | 26 |
| % Nondetects | 0% | 38% | 68% | 0% |
| Mean | 623 µS/cm | 281 µg/L | 3.60 µg/L | 8.11 su |
| Median | 645 µS/cm | 330 µg/L | <3.40[a] µg/L | 8.11 su |
| Standard Deviation | 73.4 µS/cm | 97.2 µg/L | 0.532 µg/L | 0.10 su |
| Coefficient of Variation | 0.118 | 0.346 | 0.148 | 0.0123 |
| Maximum | 707 µS/cm | 720 µg/L | 7.70 µg/L | 8.35 su |
| Number of Comparisons | 24 | 24 | 24 | 24 |
| alpha per comp ($\alpha_{adjusted}$) | 4.17E-04 | 4.17E-04 | 4.17E-04 | 2.08E-04 |
| $t_{crit,i}$ | 3.80 | 3.82 | 3.82 | 4.07 |
| Critical Mean | 907[b,c] µS/cm | 659 [b,c] µg/L | 5.67 [b,c,d] µg/L | 8.52 [b,c] su |
| Lower Critical Range | | | | 7.69 [b,c] su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

c. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

d. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

µS/cm  =  micro-Siemens per centimeter

µg/L   =  micrograms per liter

CM    =  critical mean

LOQ   =  limit of quantitation

su     =  standard unit

Table 15. Critical Means for the 216-B-63 Ditch - New for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 1 | | | |
| Date Range for Data | 4/1/2016 – 11/5/2019 | | | |
| Number of Composite Samples | 8 | 8 | 8 | 8 |
| % Nondetects | 0% | 50% | 63% | 0% |
| Mean | 640 µS/cm | 213 µg/L | 3.67 µg/L | 8.13 su |
| Median | 648 µS/cm | <330 µg/L | <3.76[a] µg/L | 8.15 su |
| Standard Deviation | 31.3 µS/cm | 59.6 µg/L | 0.474 µg/L | 0.0615 su |
| Coefficient of Variation | 0.0489 | 0.28 | 0.129 | 0.00757 |
| Maximum | 676 µS/cm | 358 µg/L | 7.70 µg/L | 8.21 su |
| Number of Comparisons | 16 | 16 | 16 | 16 |
| alpha per comp ($\alpha_{adjusted}$) | 6.25E-04 | 6.25E-04 | 6.25E-04 | 3.13E-04 |
| $t_{crit,i}$ | 5.20 | 5.20 | 5.20 | 5.86 |
| Critical Mean | 812 µS/cm | 541[b,c,d] µg/L | 6.29[b,c,d] µg/L | 8.52 su |
| Lower Critical Range | | | | 7.75 su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

c. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

d. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

µS/cm   =   micro-Siemens per centimeter

µg/L   =   micrograms per liter

CM   =   critical mean

LOQ   =   limit of quantitation

su   =   standard unit

Table 16. Critical Means for the 216-S-10 Pond and Ditch for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 1 | | | |
| Date Range for Data | 5/20/2016 – 11/8/2019 | 5/7/2014 – 11/8/2019 | 5/20/2016 – 11/8/2019 | |
| Number of Composite Samples | 8 | 12 | 8 | 8 |
| % Nondetects | 0% | 83% | 38% | 0% |
| Mean | 305 µS/cm | 210 µg/L | 4.10 µg/L | 7.61 su |
| Median | 304 µS/cm | <348[a] µg/L | 4.05 µg/L | 7.54 su |
| Standard Deviation | 8.83 µS/cm | 80.5 µg/L | 1.79 µg/L | 0.15 su |
| Coefficient of Variation | 0.0289 | 0.384 | 0.437 | 0.0198 |
| Maximum | 324 µS/cm | 720 µg/L | 7.78 µg/L | 7.85 su |
| Number of Comparisons | 20 | 20 | 20 | 20 |
| alpha per comp ($\alpha_{adjusted}$) | 5.00E-04 | 5.00E-04 | 5.00E-04 | 2.50E-04 |
| $t_{crit,i}$ | 5.41 | 4.44 | 5.41 | 6.08 |
| Critical Mean | 356 µS/cm | 581[a,b,c] µg/L | 14.4 µg/L | 8.58 su |
| Lower Critical Range | | | | 6.64 su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

c. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

| | | |
|---|---|---|
| µS/cm | = | micro-Siemens per centimeter |
| µg/L | = | micrograms per liter |
| CM | = | critical mean |
| LOQ | = | limit of quantitation |
| su | = | standard unit |

Table 17. Critical Means for the 600 NRDWL Sanitary Landfill for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 3 | | | |
| Date Range for Data | 1/8/2018 – 10/2/2019 | | | |
| Number of Composite Samples | 24 | 24 | 24 | 24 |
| % Nondetects | 0% | 58% | 67% | 0% |
| Mean | 505 µS/cm | 344 µg/L | 3.87 µg/L | 7.39 su |
| Median | 506 µS/cm | <330[a] µg/L | 3.33 µg/L | 7.39 su |
| Standard Deviation | 19.1 µS/cm | 32.6 µg/L | 1.05 µg/L | 0.0904 su |
| Coefficient of Variation | 0.0379 | 0.0948 | 0.273 | 0.0123 |
| Maximum | 541 µS/cm | 433 µg/L | 8.18 µg/L | 7.50 su |
| Number of Comparisons | 32 | 32 | 32 | 32 |
| alpha per comp ($\alpha_{adjusted}$) | 3.13E-04 | 3.13E-04 | 3.13E-04 | 1.56E-04 |
| $t_{crit,i}$ | 3.96 | 3.96 | 3.96 | 4.24 |
| Critical Mean | 582 µS/cm | 475[b,c,d] µg/L | 8.12[b,c] µg/L | 7.76 su |
| Lower Critical Range | | | | 6.98 su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

c. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

d. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

| | | |
|---|---|---|
| µS/cm | = | micro-Siemens per centimeter |
| µg/L | = | micrograms per liter |
| CM | = | critical mean |
| LOQ | = | limit of quantitation |
| su | = | standard unit |

Table 18. Critical Means for the Low-Level Waste Management Area 1 (LLWMA-1) for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 2 | | | |
| Date Range for Data | 1/14/2016 – 7/9/2019 | | | |
| Number of Composite Samples | 16 | 16 | 16 | 16 |
| % Nondetects | 0% | 50% | 44% | 0% |
| Mean | 428 µS/cm | 425 µg/L | 3.60 µg/L | 7.96 su |
| Median | 431 µS/cm | 367 µg/L | 3.36 µg/L | 7.98 su |
| Standard Deviation | 20.2 µS/cm | 142 µg/L | 1.91 µg/L | 0.117 su |
| Coefficient of Variation | 0.0472 | 0.333 | 0.531 | 0.0147 |
| Maximum | 471 µS/cm | 763 µg/L | 8.28 µg/L | 8.16 su |
| Number of Comparisons | 28 | 28 | 28 | 28 |
| alpha per comp ($\alpha_{adjusted}$) | 3.57E-04 | 3.57E-04 | 3.57E-04 | 1.79E-04 |
| $t_{crit,i}$ | 4.24 | 4.24 | 4.24 | 4.59 |
| Critical Mean | 517 µS/cm | 1,040[a,b] µg/L | 12.0 [a,b] µg/L | 8.52 su |
| Lower Critical Range | | | | 7.41 su |

a. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

b. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

µS/cm  =   micro-Siemens per centimeter

µg/L  =   micrograms per liter

su  =   standard unit

Table 19. Critical Means for Low-Level Waste Management Area 1 (LLWMA-1) - NEW for CY 2020 Comparisons [a]

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 2 | | | |
| Date Range for Data | 1/14/2016 – 7/9/2019 | | | |
| Number of Composite Samples | 16 | 16 | 16 | 16 |
| % Nondetects | 0% | 50% | 44% | 0% |
| Mean | 428 µS/cm | 425 µg/L | 3.60 µg/L | 7.96 su |
| Median | 431 µS/cm | 367 µg/L | 3.36 µg/L | 7.98 su |
| Standard Deviation | 20.2 µS/cm | 142 µg/L | 1.91 µg/L | 0.117 su |
| Coefficient of Variation | 0.0472 | 0.333 | 0.531 | 0.0147 |
| Maximum | 471 µS/cm | 763 µg/L | 8.28 µg/L | 8.16 su |
| Number of Comparisons | 20 | 20 | 20 | 20 |
| alpha per comp ($\alpha_{adjusted}$) | 5.00E-04 | 5.00E-04 | 5.00E-04 | 2.50E-04 |
| $t_{crit,i}$ | 4.07 | 4.07 | 4.07 | 4.42 |
| Critical Mean | 513 µS/cm | 1,020[b,c] µg/L | 11.6[b,c] µg/L | 8.50 su |
| Lower Critical Range | | | | 7.43 su |

a. The well network for LLWMA-1 New differs from LLWMA-1 due to the exclusion of wells 299-E28-26, 299-E26-28 and 299-E28-33 from the downgradient well list.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

c. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

| µS/cm | = | micro-Siemens per centimeter |
|---|---|---|
| µg/L | = | micrograms per liter |
| LLWMA | = | Low-Level Waste Management Area |
| su | = | standard unit |

Table 20. Critical Means for Low-Level Waste Management Area 2 (LLWMA-2) for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 1 | | | |
| Date Range for Data | 10/5/2016 – 11/7/2019 | | | |
| Number of Composite Samples | 9 | 8 | 8 | 9 |
| % Nondetects | 0% | 25% | 0% | 0% |
| Mean | 1,280 µS/cm | 868 µg/L | 8.40 µg/L | 7.79 su |
| Median | 1,270 µS/cm | 915 µg/L | 8.27 µg/L | 7.78 su |
| Standard Deviation | 139 µS/cm | 316 µg/L | 4.28 µg/L | 0.105 su |
| Coefficient of Variation | 0.109 | 0.365 | 0.509 | 0.0135 |
| Maximum | 1,460 µS/cm | 1,330 µg/L | 16.8 µg/L | 8.02 su |
| Number of Comparisons | 36 | 36 | 36 | 36 |
| alpha per comp ($\alpha_{adjusted}$) | 2.78E-04 | 2.78E-04 | 2.78E-04 | 1.39E-04 |
| $t_{crit,i}$ | 5.53 | 5.98 | 5.98 | 6.14 |
| Critical Mean | 2,090 µS/cm | 2,870 µg/L | 35.5 µg/L | 8.47 su |
| Lower Critical Range | | | | 7.11 su |

µS/cm   =   micro-Siemens per centimeter

µg/L   =   micrograms per liter

su   =   standard unit

Table 21. Critical Means for Low-Level Waste Management Area 2 (LLWMA-2) - NEW for CY2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 1 | | | |
| Date Range for Data | 10/5/2016 – 11/6/2019 | | | |
| Number of Composite Samples | 8 | 7 | 8 | 8 |
| % Nondetects | 0% | 71% | 13% | 0% |
| Mean | 587 µS/cm | 319 µg/L | 5.17 µg/L | 8.02 su |
| Median | 584 µS/cm | <494[a] µg/L | 4.78 µg/L | 8.06 su |
| Standard Deviation | 13.9 µS/cm | 101 µg/L | 2.33 µg/L | 0.0683 su |
| Coefficient of Variation | 0.0237 | 0.318 | 0.452 | 0.00852 |
| Maximum | 609 µS/cm | 720 µg/L | 11.2 µg/L | 8.06 su |
| Number of Comparisons | 16 | 16 | 16 | 16 |
| alpha per comp ($\alpha_{adjusted}$) | 6.25E-04 | 6.25E-04 | 6.25E-04 | 3.13E-04 |
| $t_{crit,i}$ | 5.20 | 65.71 | 5.20 | 5.86 |
| Critical Mean | 663 µS/cm | 937[b] µg/L | 18.1[c] µg/L | 8.44[c,d] su |
| Lower Critical Range | | | | 7.59[c,d] su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

c. Dataset not normally distributed based on Shapiro-Wilk Test (p < 0.05).

d. Dataset not log normally distributed based on Shapiro-Wilk Test (p < 0.05).

µS/cm  =  micro-Siemens per centimeter

µg/L  =  micrograms per liter

CM  =  critical mean

LOQ  =  limit of quantitation

su  =  standard unit

Table 22. Intrawell Critical Means for Low Level Waste Management Area 2 (LLWMA-2) for CY2020 Comparisons

| Statistic | 299-E34-2 | 299-E27-10 | 299-E27-11 | 299-E27-17 | 299-E27-8 | 299-E27-9 | 299-E34-10 | 299-E34-12 | 299-E34-9 |
|---|---|---|---|---|---|---|---|---|---|
| **Specific Conductance Intrawell Critical Means** | | | | | | | | | |
| Mean | 587 µS/cm | 1,280 µS/cm | 507 µS/cm | 512 µS/cm | 495 µS/cm | 1,110 µS/cm | 699 µS/cm | 567 µS/cm | 1,150 µS/cm |
| Standard Deviation | 13.9 µS/cm | 139 µS/cm | 43.9 µS/cm | 15.3 µS/cm | 19.7 µS/cm | 58.5 µS/cm | 26.5 µS/cm | 84.3 µS/cm | 277 µS/cm |
| Number of Composite Samples | 8 | 9 | 12 | 11 | 10 | 10 | 14 | 8 | 16 |
| % Non-Detects | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Maximum | 609 µS/cm | 1,460 µS/cm | 640 µS/cm | 538 µS/cm | 537 µS/cm | 1,220 µS/cm | 735 µS/cm | 699 µS/cm | 1,490 µS/cm |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| $t_{crit,i}$ | 3.00 | 2.90 | 2.72 | 2.76 | 2.82 | 2.82 | 2.65 | 3.00 | 2.60 |
| Critical Mean | 631 µS/cm | 1,710 µS/cm | 631 µS/cm | 556 µS/cm | 553 µS/cm | 1,280 µS/cm | 772 µS/cm | 835 µS/cm | 1,890 µS/cm |
| **Total Organic Carbon Intrawell Critical Means** | | | | | | | | | |
| Mean | 319 µg/L | 868 µg/L | 215 µg/L | 323 µg/L | 341 µg/L | 822 µg/L | 314 µg/L | 272 µg/L | 568 µg/L |
| Standard Deviation | 101 µg/L | 316 µg/L | 87.4 µg/L | 66.1 µg/L | 15.3 µg/L | 92.2 µg/L | 63.2 µg/L | 76.0 µg/L | 74.4 µg/L |
| Number of Composite Samples | 7 | 8 | 7 | 8 | 7 | 9 | 7 | 7 | 9 |
| % Non-Detects | 71% | 25% | 57% | 38% | 71% | 11% | 29% | 29% | 56% |
| Maximum | 720 µg/L | 1,330 µg/L | 720 µg/L | 720 µg/L | 720 µg/L | 961 µg/L | 720 µg/L | 404 µg/L | 723 µg/L |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| $t_{crit,i}$ | 3.14 | 3.00 | 3.14 | 3.00 | 3.14 | 2.90 | 3.14 | 3.14 | 2.90 |
| Critical Mean | 659 * µg/L | 1,870 µg/L | 508 * µg/L | 533 µg/L | 393 * µg/L | 1,100 µg/L | 526 µg/L | 527 µg/L | 795 * µg/L |
| **Total Organic Halides Intrawell Critical Means** | | | | | | | | | |
| Mean | 5.17 µg/L | 8.40 µg/L | 6.59 µg/L | 5.38 µg/L | 6.72 µg/L | 6.22 µg/L | 4.46 µg/L | 3.43 µg/L | 3.98 µg/L |
| Standard Deviation | 2.33 µg/L | 4.28 µg/L | 2.38 µg/L | 2.97 µg/L | 2.17 µg/L | 3.77 µg/L | 1.62 µg/L | 0.183 µg/L | 1.27 µg/L |
| Number of Composite Samples | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 |

Table 22. Intrawell Critical Means for Low Level Waste Management Area 2 (LLWMA-2) for CY2020 Comparisons

| Statistic | 299-E34-2 | 299-E27-10 | 299-E27-11 | 299-E27-17 | 299-E27-8 | 299-E27-9 | 299-E34-10 | 299-E34-12 | 299-E34-9 |
|---|---|---|---|---|---|---|---|---|---|
| % Non-Detects | 13% | 0% | 0% | 25% | 13% | 0% | 50% | 75% | 22% |
| Maximum | 11.2 µg/L | 16.8 µg/L | 10.2 µg/L | 10.8 µg/L | 10.2 µg/L | 14.6 µg/L | 7.70 µg/L | 7.70 µg/L | 6.23 µg/L |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| $t_{crit,i}$ | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 2.90 |
| Critical Mean | 12.6 µg/L | 22.0 µg/L | 14.2 µg/L | 14.8 µg/L | 13.6 µg/L | 18.2 µg/L | 9.62 µg/L | 4.02 * µg/L | 7.88 µg/L |
| **pH Measurement Intrawell Critical Means** | | | | | | | | | |
| Mean | 8.02 su | 7.79 su | 8.11 su | 8.06 su | 8.07 su | 8.00 su | 7.98 su | 8.06 su | 7.89 su |
| Standard Deviation | 0.0683 su | 0.105 su | 0.147 su | 0.0813 su | 0.0693 su | 0.0904 su | 0.0579 su | 0.107 su | 0.0753 su |
| Number of Composite Samples | 8 | 9 | 11 | 11 | 10 | 10 | 14 | 8 | 16 |
| % Non-detects | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Pooled Standard Deviation | 0.091 su | 0.091 su | 0.091 su | 0.091 su | 0.091 su | 0.091 su | 0.091 su | 0.091 su | 0.091 su |
| Pooled Sample Size | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 |
| Maximum | 8.06 su | 8.02 su | 8.40 su | 8.19 su | 8.19 su | 8.13 su | 8.09 su | 8.24 su | 8.02 su |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| $df_{pooled}$ | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| $t_{crit,i}$ | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 |
| Upper Critical Range | 8.26 su | 8.03 su | 8.35 su | 8.30 su | 8.31 su | 8.24 su | 8.22 su | 8.30 su | 8.13 su |
| Lower Critical Range | 7.77 su | 7.55 su | 7.87 su | 7.82 su | 7.83 su | 7.76 su | 7.74 su | 7.82 su | 7.65 su |

* Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

µS/cm   =   micro-Siemens per centimeter

µg/L   =   micrograms per liter

CM   =   critical mean

LOQ   =   limit of quantitation

su   =   standard unit

Table 23. Critical Means for Low-Level Waste Management Area 3 (LLWMA-3) for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 1 | | | |
| Date Range for Data | 3/2/2015 – 9/10/2018 | | | |
| Number of Composite Samples | 8 | 8 | 8 | 8 |
| % Nondetects | 0% | 50% | 13% | 0% |
| Mean | 395 µS/cm | 343 µg/L | 4.97 µg/L | 8.04 su |
| Median | 395 µS/cm | 338 µg/L | 5.15 µg/L | 8.07 su |
| Standard Deviation | 10.6 µS/cm | 17.7 µg/L | 1.29 µg/L | 0.0971 su |
| Coefficient of Variation | 0.0269 | 0.0516 | 0.26 | 0.0121 |
| Maximum | 409 µS/cm | 384 µg/L | 7.05 µg/L | 8.14 su |
| Number of Comparisons | 16 | 16 | 16 | 16 |
| alpha per comp ($\alpha_{adjusted}$) | 6.25E-04 | 6.25E-04 | 6.25E-04 | 3.13E-04 |
| $t_{crit,i}$ | 5.20 | 5.20 | 5.20 | 5.86 |
| Critical Mean | 454 µS/cm | 441[a,b] µg/L | 12.1 µg/L | 8.64 su |
| Lower Critical Range | | | | 7.44 su |

a. Dataset not normally distributed based on Shapiro-Wilk Test (p < 0.05).

b. Dataset not log normally distributed based on Shapiro-Wilk Test (p < 0.05).

| µS/cm | = | micro-Siemens per centimeter |
|---|---|---|
| µg/L | = | micrograms per liter |
| su | = | standard unit |

Table 24. Intrawell Critical Means for Low/ Level Waste Management Area 3 (LLWMA-3) for CY2020 Comparisons

| Statistic | 299-W9-2 | 299-W9-29 | 299-W10-30 | 299-W10-31 |
|---|---|---|---|---|
| **Specific Conductance Intrawell Critical Means** | | | | |
| Mean | 395 µS/cm | 406 µS/cm | 388 µS/cm | 492 µS/cm |
| Standard Deviation | 10.6 µS/cm | 9.36 µS/cm | 17.6 µS/cm | 8.75 µS/cm |
| Number of Composite Samples | 8 | 8 | 9 | 9 |
| % Non-Detects | 0% | 0% | 0% | 0% |
| Pooled Standard Deviation (log scale) | 0.03 | 0.03 | 0.03 | 0.03 |
| Pooled Sample Size | 34 | 34 | 34 | 34 |
| Maximum | 409 µS/cm | 416 µS/cm | 428 µS/cm | 505 µS/cm |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 |
| $df_{pooled}$ | 30 | 30 | 30 | 30 |
| $t_{crit,i}$ | 2.46 | 2.46 | 2.46 | 2.46 |
| Critical Mean | 426 µS/cm | 437 µS/cm | 418 µS/cm | 530 µS/cm |
| **Total Organic Carbon Intrawell Critical Means** | | | | |
| Mean | 343 µg/L | 313 µg/L | 339 µg/L | 323 µg/L |
| Standard Deviation | 17.7 µg/L | 189 µg/L | 10.7 µg/L | 169 µg/L |
| Number of Composite Samples | 8 | 8 | 8 | 8 |
| % Non-Detects | 50% | 50% | 50% | 50% |
| Maximum | 384 µg/L | 718 µg/L | 357 µg/L | 720 µg/L |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 |
| $t_{crit,i}$ | 3.00 | 3.00 | 3.00 | 3.00 |
| Critical Mean | 399 µg/L | 914 µg/L | 373 µg/L | 861 µg/L |
| **Total Organic Halides Intrawell Critical Means** | | | | |
| Mean | 4.77 µg/L | 5.83 µg/L | 15.2 µg/L | 8.27 µg/L |
| Standard Deviation | 1.74 µg/L | 1.92 µg/L | 3.58 µg/L | 1.41 µg/L |
| Number of Composite Samples | 8 | 8 | 9 | 9 |
| % Non-Detects | 3% | 3% | 3% | 3% |

Table 24. Intrawell Critical Means for Low/ Level Waste Management Area 3 (LLWMA-3) for CY2020 Comparisons

| Statistic | 299-W9-2 | 299-W9-29 | 299-W10-30 | 299-W10-31 |
|---|---|---|---|---|
| Maximum | 7.05 µg/L | 9.18 µg/L | 21.5 µg/L | 10.1 µg/L |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 |
| $t_{crit,i}$ | 3.00 | 3.00 | 2.90 | 2.90 |
| Critical Mean | 10.3 µg/L | 11.9 µg/L | 26.1 µg/L | 12.6 µg/L |
| **pH Measurement Intrawell Critical Means** | | | | |
| Mean | 8.04 su | 7.98 su | 7.94 su | 7.91 su |
| Standard Deviation | 0.0971 su | 0.0785 su | 0.0864 su | 0.0792 su |
| Number of Composite Samples | 8 | 8 | 9 | 9 |
| % Non-Detects | 0% | 0% | 0% | 0% |
| Pooled Standard Deviation | 0.0855 | 0.0855 | 0.0855 | 0.0855 |
| Pooled Sample Size | 34 | 34 | 34 | 34 |
| Maximum | 8.14 su | 8.09 su | 8.05 su | 8.04 su |
| alpha | 0.01 | 0.01 | 0.01 | 0.01 |
| $df_{pooled}$ | 30 | 30 | 30 | 30 |
| $t_{crit,i}$ | 2.75 | 2.75 | 2.75 | 2.75 |
| Upper Critical Range | 8.28 su | 8.22 su | 8.17 su | 8.15 su |
| Lower Critical Range | 7.80 su | 7.74 su | 7.70 su | 7.67 su |

µS/cm = micro-Siemens per centimeter

µg/L = micrograms per liter

su = standard unit

Table 25. Critical Means for Low-Level Waste Management Area 4 (LLWMA-4) for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | Total Organic Halides | pH Measurement |
|---|---|---|---|---|
| Number of Upgradient Wells | 1 | | | |
| Date Range for Data | 1/17/2014 – 12/18/2019 | | | |
| Number of Composite Samples | 14 | 10 | 11 | 14 |
| % Nondetects | 0% | 60% | 0% | 0% |
| Mean | 610 µS/cm | 342 µg/L | 10.1 µg/L | 8.11 su |
| Median | 607 µS/cm | <385[a] µg/L | 8.40 µg/L | 8.14 su |
| Standard Deviation | 41.7 µS/cm | 75.5 µg/L | 5.83 µg/L | 0.173 su |
| Coefficient of Variation | 0.0683 | 0.221 | 0.575 | 0.0214 |
| Maximum | 727 µS/cm | 720 µg/L | 22.1 µg/L | 8.37 su |
| Number of Comparisons | 24 | 24 | 24 | 24 |
| alpha per comp ($\alpha_{adjusted}$) | 4.17E-04 | 4.17E-04 | 4.17E-04 | 2.08E-04 |
| $t_{crit,i}$ | 4.32 | 4.91 | 4.71 | 4.70 |
| Critical Mean | 797[c] µS/cm | 731[b,c] µg/L | 38.8 µg/L | 8.95 su |
| Lower Critical Range | | | | 7.26 su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

c. Dataset not normally distributed based on Shapiro-Wilk Test (p < 0.05).

µS/cm   =   micro-Siemens per centimeter

µg/L   =   micrograms per liter

CM   =   critical mean

LOQ   =   limit of quantitation

su   =   standard unit

Table 26. Critical Means for WMA A-AX for CY 2020 Comparisons

| Statistic | Specific Conductance | Total Organic Carbon | pH Measurement |
|---|---|---|---|
| Number of Upgradient Wells | 3 | | |
| Date Range for Data | 2/1/2018 – 12/9/2019 | 3/8/2014 – 12/8/2015 | 2/1/2018 – 12/9/2019 |
| Number of Composite Samples | 26 | 24 | 26 |
| % Nondetects | 0% | 63% | 0% |
| Mean | 670 µS/cm | 360 µg/L | 7.93 su |
| Median | 646 µS/cm | <350[a] µg/L | 7.95 su |
| Standard Deviation | 53.8 µS/cm | 174 µg/L | 0.11 su |
| Coefficient of Variation | 0.0803 | 0.483 | 0.0138 |
| Maximum | 754 µS/cm | 850 µg/L | 8.12 su |
| Number of Comparisons | 32 | 32 | 32 |
| alpha per comp ($\alpha_{adjusted}$) | 3.13E-04 | 3.13E-04 | 1.56E-04 |
| $t_{crit,i}$ | 3.91 | 3.96 | 4.18 |
| Critical Mean | 884[b,c] µS/cm | 1,060[b,c,d] µg/L | 8.40 su |
| Lower Critical Range | | | 7.47 su |

a. Determination of the median includes a high percentage of non-detects at the reporting limit.

b. Dataset not normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

c. Dataset not log normally distributed based on Shapiro-Wilk Test ($p < 0.05$).

d. Percent nondetects in dataset used to calculate critical mean is greater than 50%, therefore the statistical comparison values are the larger of either the CM or the LOQ.

µS/cm  =  micro-Siemens per centimeter

µg/L  =  micrograms per liter

CM  =  critical mean

LOQ  =  limit of quantitation

su  =  standard unit

# 8   References

40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol25/xml/CFR-2010-title40-vol25-part264.xml.

40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol25/xml/CFR-2010-title40-vol25-part265.xml.

    265.92, "Sampling and Analysis."

    265.93, "Preparation, Evaluation, and Response."

*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq., Pub. L. 107-377, December 31, 2002. Available at: https://www.csu.edu/cerc/researchreports/documents/CERCLASummary1980.pdf.

ECF-Hanford-13-0013, 2014, *Calculation of Critical Means for Calendar Year 2013 RCRA Groundwater Monitoring*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080432H.

ECF-HANFORD-18-0004, 2018, *Calculation of Critical Means for Calendar Year 2018 RCRA Groundwater Monitoring*, Rev. 0, CH2M HILL  Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0064440H.

Ecology Publication 92-54, 1992, *Statistical Guidance for Ecology Site Managers*, Toxics Cleanup Program, Washington State Department of Ecology, Olympia, Washington. Available at: https://fortress.wa.gov/ecy/publications/documents/9254.pdf.

EPA 530/R-09-007, 2009, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, Office of Resource Conservation and Recovery, U.S. Environmental Protection Agency, Washington, D.C. Available at: https://www.itrcweb.org/gsmc-1/Content/Resources/Unified_Guidance_2009.pdf.

Grubbs, Frank E., 1969, "Procedures for Detecting Outlying Observations in Samples," *Technometrics* 11(1):1-21. Available at: http://web.ipac.caltech.edu/staff/fmasci/home/astro_refs/OutlierProc_1969.pdf.

*Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq. Available at: https://elr.info/sites/default/files/docs/statutes/full/rcra.pdf.

Venables, W.N., D.M. Smith, and the R Development Core Team, 2015, *An Introduction to R Notes on R: A Programming Environment for Data Analysis and Graphics*, Version 3.2.0, 105 pp. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.682.7236&rep=rep1&type=pdf.

WA7890008967, 2007, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*, as amended, Washington State Department of Ecology, Richland, Washington. Available at: https://fortress.wa.gov/ecy/nwp/permitting/hdwp/rev/8c/..

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303.

    303-400, "Interim Status Facility Standards."

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# Appendix A

# List of Upgradient and Downgradient Wells by Site and Starting Dates for Critical Means Calculations

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# A1    List of Upgradient and Downgradient Wells by Site

Table A-1 presents the list of *Resource Conservation and Recovery Act of 1976* (RCRA) Site upgradient and downgradient wells used for the critical mean calculations.

**Table A-1. List of Wells by Site**

| Site [a] | Location [b] | Well Name [c] | Use |
|---|---|---|---|
| 216-A-29 Ditch | UP | 299-E25-2 | FALSE |
| 216-A-29 Ditch | DOWN | 299-E25-238 | TRUE |
| 216-A-29 Ditch | DOWN | 299-E25-239 | TRUE |
| 216-A-29 Ditch | DOWN | 299-E25-26 | FALSE |
| 216-A-29 Ditch | DOWN | 299-E25-28 | FALSE |
| 216-A-29 Ditch | DOWN | 299-E25-32P | FALSE |
| 216-A-29 Ditch | UP | 299-E25-34 | TRUE |
| 216-A-29 Ditch | DOWN | 299-E25-35 | TRUE |
| 216-A-29 Ditch | UP | 299-E25-43 | TRUE |
| 216-A-29 Ditch | UP | 299-E25-47 | TRUE |
| 216-A-29 Ditch | DOWN | 299-E25-48 | FALSE |
| 216-A-29 Ditch | UP | 299-E26-12 | FALSE |
| 216-A-29 Ditch | UP | 299-E26-13 | TRUE |
| 216-A-29 Ditch | DOWN | 299-E26-80 | TRUE |
| 216-A-29 Ditch | DOWN | 699-43-45 | FALSE |
| 216-A-36B Crib | UP | 299-E17-1 | TRUE |
| 216-A-36B Crib | DOWN | 299-E17-14 | TRUE |
| 216-A-36B Crib | DOWN | 299-E17-15 | TRUE |
| 216-A-36B Crib | DOWN | 299-E17-16 | TRUE |
| 216-A-36B Crib | DOWN | 299-E17-18 | TRUE |
| 216-A-36B Crib | UP | 299-E17-19 | TRUE |
| 216-A-37-1 Crib | DOWN | 299-E25-17 | TRUE |
| 216-A-37-1 Crib | DOWN | 299-E25-19 | TRUE |
| 216-A-37-1 Crib | DOWN | 299-E25-20 | TRUE |
| 216-A-37-1 Crib | UP | 299-E25-35 | TRUE |
| 216-A-37-1 Crib | UP | 299-E25-47 | TRUE |
| 216-A-37-1 Crib | DOWN | 299-E25-95 | TRUE |
| 216-B-3 Pond | DOWN | 699-42-42B | TRUE |

**Table A-1. List of Wells by Site**

| Site [a] | Location [b] | Well Name [c] | Use |
|---|---|---|---|
| 216-B-3 Pond | DOWN | 699-43-43B | FALSE |
| 216-B-3 Pond | DOWN | 699-43-44 | FALSE |
| 216-B-3 Pond | DOWN | 699-43-45 | TRUE |
| 216-B-3 Pond | UP | 699-44-39B | TRUE |
| 216-B-3 Pond | UP | 699-44-43C | TRUE |
| 216-B-3 Pond | UP | 699-45-42 | TRUE |
| 216-B-63 Ditch | DOWN | 299-E27-16 | TRUE |
| 216-B-63 Ditch | DOWN | 299-E27-18 | TRUE |
| 216-B-63 Ditch | DOWN | 299-E27-19 | TRUE |
| 216-B-63 Ditch | UP | 299-E33-33 | TRUE |
| 216-B-63 Ditch | UP | 299-E34-12 | TRUE |
| 216-B-63 Ditch | UP | 299-E34-8 | TRUE |
| 216-B-63 Ditch-New | DOWN | 299-E27-16 | TRUE |
| 216-B-63 Ditch-New | DOWN | 299-E27-18 | TRUE |
| 216-B-63 Ditch-New | DOWN | 299-E33-37 | TRUE |
| 216-B-63 Ditch-New | UP | 299-E27-19 | FALSE |
| 216-B-63 Ditch-New | UP | 299-E33-33 | FALSE |
| 216-B-63 Ditch-New | UP | 299-E34-12 | FALSE |
| 216-B-63 Ditch-New | UP | 299-E34-8 | FALSE |
| 216-B-63 Ditch-New | UP | 299-E33-33 | TRUE |
| 216-S-10 Pond and Ditch | DOWN | 299-W26-13 | TRUE |
| 216-S-10 Pond and Ditch | DOWN | 299-W26-14 | TRUE |
| 216-S-10 Pond and Ditch | DOWN | 299-W27-2 | FALSE |
| 216-S-10 Pond and Ditch | DOWN | 699-32-76 | TRUE |
| 216-S-10 Pond and Ditch | DOWN | 699-33-75 | TRUE |
| 216-S-10 Pond and Ditch | UP | 699-33-76 | TRUE |
| 600 NRDWL Sanitary Landfill | DOWN | 699-25-33A | FALSE |
| 600 NRDWL Sanitary Landfill | DOWN | 699-25-34B | TRUE |
| 600 NRDWL Sanitary Landfill | DOWN | 699-25-34D | TRUE |
| 600 NRDWL Sanitary Landfill | DOWN | 699-25-34F | TRUE |
| 600 NRDWL Sanitary Landfill | DOWN | 699-26-33A | TRUE |

**Table A-1. List of Wells by Site**

| Site [a] | Location [b] | Well Name [c] | Use |
|---|---|---|---|
| 600 NRDWL Sanitary Landfill | UP | 699-26-34A | TRUE |
| 600 NRDWL Sanitary Landfill | DOWN | 699-26-34B | TRUE |
| 600 NRDWL Sanitary Landfill | UP | 699-26-35A | TRUE |
| 600 NRDWL Sanitary Landfill | DOWN | 699-26-35C | FALSE |
| 600 NRDWL Sanitary Landfill | UP | 699-26-38 | TRUE |
| LLWMA-1 | DOWN | 299-E28-26 | TRUE |
| LLWMA-1 | DOWN | 299-E28-27 | TRUE |
| LLWMA-1 | DOWN | 299-E28-28 | TRUE |
| LLWMA-1 | DOWN | 299-E28-33 | FALSE |
| LLWMA-1 | UP | 299-E32-3 | TRUE |
| LLWMA-1 | UP | 299-E33-266 | TRUE |
| LLWMA-1 | DOWN | 299-E33-28 | TRUE |
| LLWMA-1 | DOWN | 299-E33-29 | TRUE |
| LLWMA-1-New | DOWN | 299-E28-26 | FALSE |
| LLWMA-1-New | DOWN | 299-E28-27 | TRUE |
| LLWMA-1-New | DOWN | 299-E28-28 | FALSE |
| LLWMA-1-New | DOWN | 299-E28-33 | FALSE |
| LLWMA-1-New | UP | 299-E32-3 | TRUE |
| LLWMA-1-New | UP | 299-E33-266 | TRUE |
| LLWMA-1-New | DOWN | 299-E33-28 | TRUE |
| LLWMA-1-New | DOWN | 299-E33-29 | TRUE |
| LLWMA-2 | UP | 299-E27-10 | TRUE |
| LLWMA-2 | DOWN | 299-E27-11 | TRUE |
| LLWMA-2 | DOWN | 299-E27-17 | TRUE |
| LLWMA-2 | DOWN | 299-E27-8 | TRUE |
| LLWMA-2 | DOWN | 299-E27-9 | TRUE |
| LLWMA-2 | DOWN | 299-E34-10 | TRUE |
| LLWMA-2 | DOWN | 299-E34-12 | TRUE |
| LLWMA-2 | DOWN | 299-E34-2 | TRUE |
| LLWMA-2 | DOWN | 299-E34-9 | TRUE |
| LLWMA-2-New | UP | 299-E27-10 | FALSE |

**Table A-1. List of Wells by Site**

| Site [a] | Location [b] | Well Name [c] | Use |
|---|---|---|---|
| LLWMA-2-New | DOWN | 299-E27-11 | TRUE |
| LLWMA-2-New | DOWN | 299-E27-17 | FALSE |
| LLWMA-2-New | DOWN | 299-E27-8 | TRUE |
| LLWMA-2-New | DOWN | 299-E27-9 | TRUE |
| LLWMA-2-New | DOWN | 299-E34-10 | FALSE |
| LLWMA-2-New | DOWN | 299-E34-12 | FALSE |
| LLWMA-2-New | UP | 299-E34-2 | TRUE |
| LLWMA-2-New | UP | 299-E34-9 | FALSE |
| LLWMA-3 | DOWN | 299-W10-29 | TRUE |
| LLWMA-3 | DOWN | 299-W10-30 | TRUE |
| LLWMA-3 | DOWN | 299-W10-31 | TRUE |
| LLWMA-3 | UP | 299-W9-2 | TRUE |
| LLWMA-4 | DOWN | 299-W15-152 | TRUE |
| LLWMA-4 | DOWN | 299-W15-17 | FALSE |
| LLWMA-4 | DOWN | 299-W15-224 | TRUE |
| LLWMA-4 | DOWN | 299-W15-30 | TRUE |
| LLWMA-4 | DOWN | 299-W15-83 | TRUE |
| LLWMA-4 | DOWN | 299-W15-94 | TRUE |
| LLWMA-4 | UP | 299-W17-1 | FALSE |
| LLWMA-4 | UP | 299-W18-21 | TRUE |
| LLWMA-4 | UP | 299-W18-22 | FALSE |
| LLWMA-4 | DOWN | 299-W18-40 | FALSE |
| WMA A-AX | UP | 299-E24-20 | TRUE |
| WMA A-AX | UP | 299-E24-22 | TRUE |
| WMA A-AX | UP | 299-E24-33 | TRUE |
| WMA A-AX | DOWN | 299-E25-2 | TRUE |
| WMA A-AX | DOWN | 299-E25-237 | TRUE |
| WMA A-AX | DOWN | 299-E25-40 | TRUE |
| WMA A-AX | DOWN | 299-E25-93 | TRUE |
| WMA A-AX | DOWN | 299-E25-94 | TRUE |

a. Site is the RCRA site.

**Table A-1. List of Wells by Site**

| Site [a] | Location [b] | Well Name [c] | Use |
|---|---|---|---|

b. Location is the specified location (upgradient or downgradient) of the well from the RCRA site.

c. Well name is the name of the well.

| | | |
|---|---|---|
| LLWMA | = | Low-Level Waste Management Area |
| NRDWL | = | nonradioactive dangerous waste landfill |
| RCRA | = | *Resource Conservation and Recovery Act of 1976* |
| WMA | = | waste management area nonradioactive dangerous waste landfill |

# A2    Starting Dates for Critical Means Calculations

Table A-2 presents the list of the starting dates for the critical mean calculations.

Table A-2. Starting Dates for Critical Mean Calculations

| Site | Analyte | Start Date | Number of Available Samples |
|---|---|---|---|
| 216-A-29 Ditch | Total organic halides | 1/16/2018 | 33 |
| 216-A-29 Ditch | Total organic carbon | 1/16/2018 | 32 |
| 216-A-29 Ditch | pH Measurement | 1/16/2018 | 33 |
| 216-A-29 Ditch | Specific Conductance | 1/16/2018 | 33 |
| 216-A-36B Crib | Total organic halides | 7/8/2016 | 19 |
| 216-A-36B Crib | Total organic carbon | 7/8/2016 | 19 |
| 216-A-36B Crib | pH Measurement | 7/8/2016 | 21 |
| 216-A-36B Crib | Specific Conductance | 7/8/2016 | 21 |
| 216-A-37-1 Crib | Total organic halides | 1/7/2016 | 29 |
| 216-A-37-1 Crib | Total organic carbon | 1/7/2016 | 29 |
| 216-A-37-1 Crib | pH Measurement | 1/7/2016 | 29 |
| 216-A-37-1 Crib | Specific Conductance | 1/7/2016 | 29 |
| 216-B-3 Pond | Total organic halides | 9/29/2015 | 23 |
| 216-B-3 Pond | Total organic carbon | 9/29/2015 | 24 |
| 216-B-3 Pond | pH Measurement | 9/29/2015 | 27 |
| 216-B-3 Pond | Specific Conductance | 9/29/2015 | 27 |
| 216-B-63 Ditch | Total organic halides | 4/1/2016 | 25 |
| 216-B-63 Ditch | Total organic carbon | 4/1/2016 | 25 |
| 216-B-63 Ditch | pH Measurement | 4/1/2016 | 26 |
| 216-B-63 Ditch | Specific Conductance | 4/1/2016 | 26 |
| 216-B-63 Ditch-New | Total organic halides | 4/1/2016 | 8 |
| 216-B-63 Ditch-New | Total organic carbon | 4/1/2016 | 8 |

Table A-2. Starting Dates for Critical Mean Calculations

| Site | Analyte | Start Date | Number of Available Samples |
|------|---------|-----------|----------------------------|
| 216-B-63 Ditch-New | pH Measurement | 4/1/2016 | 8 |
| 216-B-63 Ditch-New | Specific Conductance | 4/1/2016 | 8 |
| 216-S-10 Pond and Ditch | Total organic halides | 5/20/2016 | 8 |
| 216-S-10 Pond and Ditch | Total organic carbon | 5/7/2014 | 12 |
| 216-S-10 Pond and Ditch | pH Measurement | 5/20/2016 | 8 |
| 216-S-10 Pond and Ditch | Specific Conductance | 5/20/2016 | 8 |
| LLWMA-1 | Total organic halides | 1/14/2016 | 16 |
| LLWMA-1 | Total organic carbon | 1/14/2016 | 16 |
| LLWMA-1 | pH Measurement | 1/14/2016 | 16 |
| LLWMA-1 | Specific Conductance | 1/14/2016 | 16 |
| LLWMA-1-New | Total organic halides | 1/14/2016 | 16 |
| LLWMA-1-New | Total organic carbon | 1/14/2016 | 16 |
| LLWMA-1-New | pH Measurement | 1/14/2016 | 16 |
| LLWMA-1-New | Specific Conductance | 1/14/2016 | 16 |
| LLWMA-2 | Total organic halides | 10/5/2016 | 8 |
| LLWMA-2 | Total organic carbon | 10/5/2016 | 8 |
| LLWMA-2 | pH Measurement | 10/5/2016 | 9 |
| LLWMA-2 | Specific Conductance | 10/5/2016 | 9 |
| LLWMA-2-New | Total organic halides | 10/5/2016 | 8 |
| LLWMA-2-New | Total organic carbon | 10/5/2016 | 7 |
| LLWMA-2-New | pH Measurement | 10/5/2016 | 8 |
| LLWMA-2-New | Specific Conductance | 10/5/2016 | 8 |
| LLWMA-3 | Total organic halides | 3/20/2017 | 8 |
| LLWMA-3 | Total organic carbon | 3/20/2017 | 8 |

Table A-2. Starting Dates for Critical Mean Calculations

| Site | Analyte | Start Date | Number of Available Samples |
|------|---------|------------|------------------------------|
| LLWMA-3 | pH Measurement | 3/20/2017 | 8 |
| LLWMA-3 | Specific Conductance | 3/20/2017 | 8 |
| LLWMA-4 | Total organic halides | 1/17/2014 | 11 |
| LLWMA-4 | Total organic carbon | 1/17/2014 | 10 |
| LLWMA-4 | pH Measurement | 1/17/2014 | 14 |
| LLWMA-4 | Specific Conductance | 1/17/2014 | 14 |
| 600 NRDWL Sanitary Landfill | Total organic halides | 1/8/2018 | 24 |
| 600 NRDWL Sanitary Landfill | Total organic carbon | 1/8/2018 | 24 |
| 600 NRDWL Sanitary Landfill | pH Measurement | 1/8/2018 | 24 |
| 600 NRDWL Sanitary Landfill | Specific Conductance | 1/8/2018 | 24 |
| WMA A-AX | Total organic halides | 3/5/2014 | 0 |
| WMA A-AX | Total organic carbon | 3/5/2014 | 24 |
| WMA A-AX | pH Measurement | 2/1/2018 | 26 |
| WMA A-AX | Specific Conductance | 2/1/2018 | 26 |

LLWMA = Low-Level Waste Management Area

NRDWL = nonradioactive dangerous waste landfill

WMA = waste management area nonradioactive dangerous waste landfill

# Appendix B

# Critical Means Analysis R Code

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# B1    Critical Means Analysis R Code

Appendix B includes the R code used to process the data and calculate critical means for each site.

```
#----------------------------------------------------------------------------#
#--This script imports data for the RCRA Critical Means Calculations - 2020
#--By: E. DiFilippo (SSP&A)
#--R Version: 3.1.3
#--Package data.table version: 1.9.4
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Set working directory--#
DIR <- 'Z:/1639_HANFORD_FY2020/66007-43 RCRA Regulatory Support and Data Evaluation_Reduction/Critical Means'
setwd(DIR)
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Load Libraries--#
library(data.table)
library(XLConnect)
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Import User-Defined Functions--#
source('R_Functions/readCHEMHEIS.R')
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Set Site-Wide Error Rate--#
ALPHA <- 0.01
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Import Chemistry Data from HEIS--#
DATA1 <- readCHEMHEIS('Data/Data Pull - 12-9-2019/qryChemHeis1.txt')
DATA2 <- readCHEMHEIS('Data/Data Pull - 12-9-2019/qryChemHeis2.txt')
DATA <- rbind(DATA1,DATA2)
DATA$EVENT <- as.Date(DATA$EVENT)
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Import RCRA Site and Wells List--#
RCRA <- loadWorkbook('Data/Received from Art Lee - 1-15-2020/RCRA_Wells_for_2020_CM_Calcs.xlsx')
RCRASITES <- readWorksheet(RCRA,sheet = 'Well_Network',header = TRUE)
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Subset Date After 2004--#
DATA <- DATA[EVENT >= as.Date(ISOdate(2004,01,01))]
DATA <- DATA[EVENT < as.Date(ISOdate(2020,01,01))]
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Subset by Analyte--#
AN <- c('pH Measurement','Specific Conductance','Total organic halides','Total organic carbon')
DATA <- subset(DATA,DATA$ANALYTE %in% AN)
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Import RCRA Site Closure Samples--#
CLOS <- fread('Data/ClosureSamples_01302017.csv')
CLOS$EVENT <- as.Date(as.POSIXct(CLOS$Date_Collected,format='%m/%d/%Y',tz='UTC'))
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Remove Closure Samples--#
ROW <- which(DATA$NAME %in% CLOS$Well & month(DATA$EVENT) == 12 & year(DATA$EVENT) == 2016)
DATA <- DATA[!ROW,]
#----------------------------------------------------------------------------#


#----------------------------------------------------------------------------#
#--Remove TOC Outlier--#
ROW <- which(DATA$NAME == '699-26-38' & DATA$ANALYTE == 'Total organic carbon' &
```

```
        DATA$EVENT == as.Date(ISOdate(2016,10,17)))
DATA <- DATA[!ROW,]
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Drop wells identified but not used--#
RCRASITES <- subset(RCRASITES, Use.for.Statistical.Evaluation == TRUE )
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Identify nonDetects; TRUE indicates nondetect--#
DATA$NDS <- ifelse(DATA$LABQ %like% 'U',TRUE,FALSE)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Identify Data to Remove Based on Review Qualifiers--#
DATA$REVIEW_RM <- ifelse(DATA$REVIEWQ %like% 'Y' | DATA$REVIEWQ %like% 'R',TRUE,FALSE)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--use only data from 'routine' or verification collection purpose--#
DATA$COLLECT_RM <- ifelse(DATA$COLLECTION_PURPOSE %in% c("R",'VER'),FALSE,TRUE)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Create Intrawell Datasets--#
INTRASITES <- subset(RCRASITES,RCRASITES$RCRA_Site %in% c('LLWMA-2','LLWMA-3'))

INTRA <- subset(DATA,DATA$NAME %in% INTRASITES$Well_Name)
INTRA <- list(INTRASITES = INTRASITES,
        DATA = INTRA)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Create Interwell Datasets--#
INTER <- list(INTERSITES = RCRASITES,
        DATA = DATA)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Save Initial Datasets--#
save(INTRA,file='Data/Runs - 1-13-2020/Intrawell.RData')
save(INTER,file='Data/Runs - 1-13-2020/Interwell.RData')
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--This script calculates the Critical Means for Hanford RCRA Areas for CY-2020
#--Interwell Method
#--Script written by: E. DiFilippo (SSP&A): modified from ECF-HANFORD-13-0013, REV. 0
#--R Version: 3.1.3
#--Package data.table version: 1.10.4.2
#--Package EnvStats version: 2.1.0
#--Package outliers version: 0.14
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Set working directory--#
DIR <- 'Z:/1639_HANFORD_FY2020/66007-43 RCRA Regulatory Support and Data Evaluation_Reduction/Critical Means'
setwd(DIR)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Load Libraries--#
library(data.table)
library(EnvStats)
library(outliers)
library(XLConnect)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
```

```
#--Import Interwell Dataset--#
load('Data/Runs - 1-13-2020/Interwell.RData')
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Set Site-Wide Error Rate--#
ALPHA <- 0.01
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Import Staring Dates--#
RCRA <- loadWorkbook('Data/Received from Art Lee - 1-15-2020/RCRA_Wells_for_2020_CM_Calcs.xlsx')
SDATES <- readWorksheet(RCRA,sheet = 'Start_Dates',header = TRUE)
SDATES$START_DATE <- as.Date(as.POSIXct(SDATES$START_DATE,format='%m/%d/%Y',tz='UTC'))
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Subset for Upgradient Wells--#
UP <- as.data.table(subset(INTER$INTERSITES,INTER$INTERSITES$Loc == 'UP'))
DATA <- subset(INTER$DATA,INTER$DATA$NAME %in% UP$Well_Name)
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Remove Data Based on Review Qualifiers and Collection Purpose--#
DATA <- DATA[REVIEW_RM == FALSE]
DATA <- DATA[COLLECT_RM == FALSE]
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Merge Sample Data and Well Info Data--#
setkey(DATA,NAME)
setkey(UP,Well_Name)
DATA <- UP[DATA,allow.cartesian=TRUE]
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Check units consistancy--#
UNITCHECK <- aggregate(DATA$UNIT, by=list(DATA$ANALYTE),
            function(x){length(unique(x))})
if(max(UNITCHECK$x) > 1){
  stop("Different units - check")
}
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Calculate the number of comparison made at each site--#
NCOMP <- data.table(as.data.frame(table(INTER$INTERSITES$RCRA_Site)))
setnames(NCOMP,colnames(NCOMP),c("Site","NCOMP"))
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Create lists of sites and analyte names--#
SITES <- sort(unique(DATA$RCRA_Site))
ANALYTES <- unique(DATA$ANALYTE)
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Calculating Summary Statistics for each Well by Sample Date
DATA_SUM <- data.table(DATA)[,list(N_NDS=sum(NDS),
                  N_SAMPLE=length(NDS),
                  PROPND=sum(NDS)/length(NDS),
                  MEAN_REPORTED=mean(VAL),
                  DETLIMIT=min(VAL),
                  MEAN_DETECTS=mean(VAL[!NDS]),
                  SD_DETECTS=sd(VAL[!NDS]),
                  CV_DETECTS=sd(VAL[!NDS])/mean(VAL[!NDS])),
             by=c("RCRA_Site","Loc","Well_Name","EVENT","ANALYTE")]
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
```

```
#--Identify nonDetects; TRUE indicates nondetect for Summary Dataset--#
DATA_SUM$NDS <- ifelse(DATA_SUM$PROPND == 1,TRUE,FALSE)
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--Calculate Summary Statistics for Each Site including NDs--#
DATA_SUM_COUNTS <- data.table(DATA_SUM)[,list(ALL_NDS=sum(PROPND==1),
                        N_SAMPLES=length(PROPND),
                        PROPNDALL=round(100*sum(PROPND==1)/length(PROPND))),
                    by=c("ANALYTE","RCRA_Site")]
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--Creating data frame to place results for exporting--#
OUT <- NULL
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--Loop through all Sites--#
for(i in 1:length(SITES)) {

  #---------------------------------------------------------------------------#
  #--Subsetting dataset by Site--#
  SUB <- DATA_SUM[RCRA_Site == SITES[i]]
  #---------------------------------------------------------------------------#


  #---------------------------------------------------------------------------#
  #--Number of comparisons--#
  NCOMP_SUB <- subset(NCOMP,Site == SITES[i])$NCOMP * length(ANALYTES)
  #---------------------------------------------------------------------------#


  #---------------------------------------------------------------------------#
  #--Analyte Loop--#
  for(j in 1:length(ANALYTES)){

    #---------------------------------------------------------------------------#
    #--Subset Data by Analyte--#
    ANALYTE_SUB <- SUB[ANALYTE == ANALYTES[j]]
    #---------------------------------------------------------------------------#


    #---------------------------------------------------------------------------#
    #--Subset data by start date--#
    STARTDATE <- subset(SDATES,SDATES$RCRA_Site == SITES[i] & SDATES$ANALYTE == ANALYTES[j])
    if(SITES[i] == '216-S-10 Pond and Ditch' & ANALYTES[j] == 'Total organic carbon'){
      STARTDATE$START_DATE <- as.Date(ISOdate(2014,05,07))
    }
    ANALYTE_SUB <- subset(ANALYTE_SUB,ANALYTE_SUB$EVENT >= STARTDATE$START_DATE)
    #---------------------------------------------------------------------------#


    #---------------------------------------------------------------------------#
    #--Skip Analytes with No Data--#
    if(nrow(ANALYTE_SUB) == 0){
      next
    }
    #---------------------------------------------------------------------------#


    #---------------------------------------------------------------------------#
    #--Handling Non-detects--#
    if(mean(ANALYTE_SUB$NDS) <= 0.1){

      ND_METHOD <- "HALF.RL"
      ANALYTE_SUB$ADJVAL <- ifelse(ANALYTE_SUB$NDS ==
TRUE,ANALYTE_SUB$MEAN_REPORTED/2,ANALYTE_SUB$MEAN_REPORTED)
      MN <- mean(ANALYTE_SUB$ADJVAL)
      SD <- sd(ANALYTE_SUB$ADJVAL)

    } else {

      ND_METHOD <- "Kaplan-Meier"
```

```
  KM <- enparCensored(ANALYTE_SUB$MEAN_REPORTED,
             ANALYTE_SUB$NDS)
  MN <- as.numeric(KM$parameters[1])
  SD <- as.numeric(KM$parameters[2])


}
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--Determining Critical Values for Student t-Test--#
if(ANALYTES[j] == 'pH Measurement'){
  ALPHA_CRIT <- (ALPHA/NCOMP_SUB)/2
}        else {
  ALPHA_CRIT <- ALPHA/NCOMP_SUB
}

N <- nrow(ANALYTE_SUB)
TCRIT <- qt(ALPHA_CRIT,df=N-1,lower.tail=FALSE,log=FALSE)
CMUP <- MN + TCRIT *SD * sqrt(1 + 1/N)
CMDW <- MN - TCRIT *SD * sqrt(1 + 1/N)
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--testing for Normality--#
SHAPIRO_NORM <- try(shapiro.test(ANALYTE_SUB$MEAN_REPORTED)$p.value, silent=TRUE)
SHAPIRO_LOG <- try(shapiro.test(log(ANALYTE_SUB$MEAN_REPORTED))$p.value, silent=TRUE)

#--Returns dummy value if test is an error--#
if(class(SHAPIRO_NORM) =="try-error") SHAPIRO_NORM <- -999
if(class(SHAPIRO_LOG) =="try-error") SHAPIRO_LOG <- -999
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--Outliers Analysis--#
GRUBBS <- grubbs.test(ANALYTE_SUB$MEAN_REPORTED, type=10, opposite=FALSE, two.sided=FALSE)
GRUBBSLOG <- grubbs.test(log(ANALYTE_SUB$MEAN_REPORTED), type=10, opposite=FALSE, two.sided=FALSE)
GRUBBS_OUT = GRUBBS$alt
GRUBBSLOG_OUT = GRUBBSLOG$alt
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--Summary of Analysis--#
OUTPUT_SUM <- data.frame(Site = unique(ANALYTE_SUB$RCRA_Site),
            UpgradientWells = nrow(UP[RCRA_Site == SITES[i]]),
            Analyte = ANALYTES[j],
            Start_Date = min(STARTDATE$START_DATE),
            End_Date = max(ANALYTE_SUB$EVENT),
            N = N,
            Prob_ND = mean(ANALYTE_SUB$NDS),
            Mean = MN,
            Median = median(ANALYTE_SUB$MEAN_REPORTED),
            SD = SD,
            CV = SD/MN,
            Max = max(ANALYTE_SUB$MEAN_REPORTED),
            NCOMP = NCOMP_SUB,
            ACrit = ALPHA_CRIT,
            TCrit = TCRIT,
            CMDW = CMDW,
            CMUP = CMUP,
            Shapiro_Norm = SHAPIRO_NORM,
            Shaprio_Log = SHAPIRO_LOG,
            Grubbs = GRUBBS$p.value,
            Grubbs_log = GRUBBSLOG$p.value,
            Grubbs_Out = GRUBBS_OUT,
            Grubbslog_Out = GRUBBSLOG_OUT,
            ND_Method = ND_METHOD)
#---------------------------------------------------------------------------#


#---------------------------------------------------------------------------#
#--Output Matrix--#
```

```
    OUT  <- rbind(OUT, OUTPUT_SUM)
    #-------------------------------------------------------------------------#
  }
  #-------------------------------------------------------------------------#
}
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Export output matrix--#
FILE <- paste0('Output/Runs - 1-13-2020/HANFORD-CRITICAL_MEANS-INTERWELL_2019_',as.character(Sys.Date()),'.csv')
write.table(OUT,FILE, sep = ",", row.names = FALSE)
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--This script calculates the Critical Means for Hanford RCRA Areas for CY-2020
#--Intrawell Method for LLWMA-2 and LLWMA-3
#--Script written by: E. DiFilippo (SSP&A): modified from ECF-HANFORD-13-0013, REV. 0
#--R Version: 3.1.3
#--Package data.table version: 1.10.4-3
#--Package EnvStats version: 2.1.0
#--Package outliers version: 0.14
#--Package lawstat version: 3.2
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Set working directory--#
DIR <- 'Z:/1639_HANFORD_FY2020/66007-43 RCRA Regulatory Support and Data Evaluation_Reduction/Critical Means'
setwd(DIR)
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Load Libraries--#
library(data.table)
library(EnvStats)
library(XLConnect)
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Import Interwell Dataset--#
load('Data/Runs - 1-13-2020/Intrawell.RData')
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Import Staring Dates--#
RCRA <- loadWorkbook('Data/Received from Art Lee - 1-15-2020/RCRA_Wells_for_2020_CM_Calcs.xlsx')
SDATES <- readWorksheet(RCRA,sheet = 'Start_Dates',header = TRUE)
SDATES$START_DATE <- as.Date(as.POSIXct(SDATES$START_DATE,format='%m/%d/%Y',tz='UTC'))
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Subset for Upgradient Wells--#
SITES <- as.data.table(INTRA$INTRASITES)
DATA <- INTRA$DATA
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Remove Data Based on Review Qualifiers and Collection Purpose--#
DATA <- DATA[REVIEW_RM == FALSE]
DATA <- DATA[COLLECT_RM == FALSE]
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Merge Sample Data and Well Info Data--#
setkey(DATA,NAME)
setkey(SITES,Well_Name)
DATA <- SITES[DATA]
#-------------------------------------------------------------------------#


#-------------------------------------------------------------------------#
#--Check units consistancy--#
```

```
UNITCHECK <- aggregate(DATA$UNIT, by=list(DATA$ANALYTE),
                function(x){length(unique(x))})
if(max(UNITCHECK$x) > 1){
  stop("Different units - check")
}
#-----------------------------------------------------------------------------#

#-----------------------------------------------------------------------------#
#--Calculate the number of comparison made at each site--#
NCOMP <- data.table(as.data.frame(table(INTRA$INTRASITES$RCRA_Site)))
setnames(NCOMP,colnames(NCOMP),c("Site","NCOMP"))
#-----------------------------------------------------------------------------#

#-----------------------------------------------------------------------------#
#--Create lists of sites--#
SITES <- sort(unique(DATA$RCRA_Site))
#-----------------------------------------------------------------------------#

#-----------------------------------------------------------------------------#
#--Calculating Summary Statistics for each Well by Sample Date
DATA_SUM <- data.table(DATA)[,list(N_NDS=sum(NDS),
                    N_SAMPLE=length(NDS),
                    PROPND=sum(NDS)/length(NDS),
                    MEAN_REPORTED=mean(VAL),
                    DETLIMIT=min(VAL),
                    MEAN_DETECTS=mean(VAL[!NDS]),
                    SD_DETECTS=sd(VAL[!NDS]),
                    CV_DETECTS=sd(VAL[!NDS])/mean(VAL[!NDS])),
                by=c("RCRA_Site","Loc","Well_Name","EVENT","ANALYTE")]
#-----------------------------------------------------------------------------#

#-----------------------------------------------------------------------------#
#--Identify nonDetects; TRUE indicates nondetect for Summary Dataset--#
DATA_SUM$NDS <- ifelse(DATA_SUM$PROPND == 1,TRUE,FALSE)
#-----------------------------------------------------------------------------#

#-----------------------------------------------------------------------------#
#--Calculate Summary Statistics for Each Site including NDs--#
DATA_SUM_COUNTS <- data.table(DATA_SUM)[,list(ALL_NDS=sum(PROPND==1),
                        N_SAMPLES=length(PROPND),
                        PROPNDALL=round(100*sum(PROPND==1)/length(PROPND))),
                    by=c("ANALYTE","RCRA_Site")]
#-----------------------------------------------------------------------------#

#-----------------------------------------------------------------------------#
#--Creating data frame to place results for exporting--#
OUT <- NULL
#-----------------------------------------------------------------------------#

#-----------------------------------------------------------------------------#
#--Loop through Each Site--#
for(j in 1:length(SITES)){

  #-----------------------------------------------------------------------------#
  #--Subset by Site--#
  SUB <- DATA_SUM[RCRA_Site == SITES[j]]
  #-----------------------------------------------------------------------------#

  #-----------------------------------------------------------------------------#
  #--Create List of Analytes and Wells--#
  ANALYTES <- sort(unique(SUB$ANALYTE))
  WELLS <- sort(unique(SUB$Well_Name))
  #-----------------------------------------------------------------------------#

  #-----------------------------------------------------------------------------#
  #--Loop through Each Analyte--#
  for(i in 1:length(ANALYTES)) {

    #-----------------------------------------------------------------------------#
    #--Subsetting dataset by Site--#
```

```
  ANALYTE_SUB <- SUB[ANALYTE==ANALYTES[i]]
  if(SITES[j] == "116-N-3 Crib" & ANALYTES[i] == "Specific Conductance"){
    ANALYTE_SUB <- ANALYTE_SUB[MEAN_REPORTED < 700]
  }
  #-------------------------------------------------------------------------#


  #-------------------------------------------------------------------------#
  #--Subset data by start date--#
  STARTDATE <- subset(SDATES,SDATES$RCRA_Site == SITES[j] & SDATES$ANALYTE == ANALYTES[i])
  ANALYTE_SUB <- subset(ANALYTE_SUB,ANALYTE_SUB$EVENT >= min(STARTDATE$START_DATE))
  if(nrow(ANALYTE_SUB) == 0){
    next
  }
  #-------------------------------------------------------------------------#


  #-------------------------------------------------------------------------#
  #--Determine Methodology for Handling Non-Detects--#
  if(mean(ANALYTE_SUB$NDS) <= 0.1){

    #-------------------------------------------------------------------------#
    #--Set ND Method and Calculate 1/2 NDs--#
    ND_METHOD <- "HALF.RL"
    ANALYTE_SUB$ADJVAL <- ifelse(ANALYTE_SUB$NDS ==
TRUE,ANALYTE_SUB$MEAN_REPORTED/2,ANALYTE_SUB$MEAN_REPORTED)
    #-------------------------------------------------------------------------#


    #-------------------------------------------------------------------------#
    #--Calculate Statistics for Pooled Variance--#
    if (ANALYTES[i] == 'pH Measurement'){
      SD <- data.table(ANALYTE_SUB)[,list(N=length(NDS),
                          SD=sd(ADJVAL),
                          VAR=var(ADJVAL)),
                      by=c('Well_Name')]
    } else {
      SD <- data.table(ANALYTE_SUB)[,list(N=length(NDS),
                          SD=sd(log(ADJVAL)),
                          VAR=var(log(ADJVAL))),
                      by=c('Well_Name')]
    }
    #-------------------------------------------------------------------------#


    #-------------------------------------------------------------------------#
    #--Calculate Summary Statistics by Well--#
    STATS <- data.table(ANALYTE_SUB)[,list(MEAN=mean(ADJVAL),
                        VAR=var(ADJVAL),
                        SD=sd(ADJVAL),
                        MEAN_Log=mean(log(ADJVAL)),
                        VAR_Log=var(log(ADJVAL)),
                        SD_Log=sd(log(ADJVAL)),
                        N=length(ADJVAL),
                        PNDS=mean(ANALYTE_SUB$NDS),
                        MAX=max(MEAN_REPORTED,na.rm=TRUE),
                        Median=median(MEAN_REPORTED, na.rm=TRUE),
                        Max.date=max(EVENT, na.rm=TRUE)),
                    by=c('RCRA_Site','Well_Name','ANALYTE')]
    #-------------------------------------------------------------------------#


  } else {

    #-------------------------------------------------------------------------#
    #--Set ND Method--#
    ND_METHOD <- "Kaplan-Meier"
    #-------------------------------------------------------------------------#


    #-------------------------------------------------------------------------#
    #--Set-up SUmmary Tables--#
    STATS <- NULL
    SD <- NULL
    #-------------------------------------------------------------------------#
```

```
#------------------------------------------------------------------------#
#--Loop Through Each Well--#
for(k in 1:length(WELLS)){

 #------------------------------------------------------------------------#
 #--Subset by Well--#
 WELL_SUB <- subset(ANALYTE_SUB,ANALYTE_SUB$Well_Name == WELLS[k])
 #------------------------------------------------------------------------#


 #------------------------------------------------------------------------#
 #--Calculate Natural Log Values--#
 if (ANALYTES[i] == 'pH Measurement'){
  WELL_SUB$ADJVAL <- WELL_SUB$MEAN_REPORTED
 } else {
  WELL_SUB$ADJVAL <- log(WELL_SUB$MEAN_REPORTED)
 }
 #------------------------------------------------------------------------#


 #------------------------------------------------------------------------#
 #--Determine Statistics--#
 if(mean(WELL_SUB$NDS) == 0){

  N <- length(WELL_SUB$NDS)
  MEAN <- mean(WELL_SUB$MEAN_REPORTED)
  MEAN_Log <- mean(log(WELL_SUB$MEAN_REPORTED))
  Sigma <- sd(WELL_SUB$MEAN_REPORTED)
  Sigma_Log <- sd(log(WELL_SUB$MEAN_REPORTED))
  VAR <- var(WELL_SUB$MEAN_REPORTED)
  VAR_Log <- var(log(WELL_SUB$MEAN_REPORTED))
  Median <- median(WELL_SUB$MEAN_REPORTED)
  Median_log <- median(log(WELL_SUB$MEAN_REPORTED))
  MaxDate <- max(WELL_SUB$EVENT,na.rm=TRUE)

 } else if(mean(WELL_SUB$NDS) > 0 & mean(WELL_SUB$NDS) <= 0.1){

  WELL_SUB$ADJVAL <- ifelse(WELL_SUB$NDS == TRUE,WELL_SUB$MEAN_REPORTED/2,WELL_SUB$MEAN_REPORTED)

  N <- length(WELL_SUB$NDS)
  MEAN <- mean(WELL_SUB$ADJVAL)
  MEAN_Log <- mean(log(WELL_SUB$ADJVAL))
  Sigma <- sd(WELL_SUB$ADJVAL)
  Sigma_Log <- sd(log(WELL_SUB$ADJVAL))
  VAR <- var(WELL_SUB$ADJVAL)
  VAR_Log <- var(log(WELL_SUB$ADJVAL))
  Median <- median(WELL_SUB$ADJVAL)
  Median_log <- median(log(WELL_SUB$ADJVAL))
  MaxDate <- max(WELL_SUB$EVENT,na.rm=TRUE)

 } else {

  KM <- enparCensored(WELL_SUB$MEAN_REPORTED,
             WELL_SUB$NDS)
  KM_log <- enparCensored(WELL_SUB$ADJVAL,
               WELL_SUB$NDS)

  N <- length(WELL_SUB$NDS)
  MEAN <- as.numeric(KM$parameters[1])
  MEAN_Log <- as.numeric(KM_log$parameters[1])
  Sigma <- as.numeric(KM$parameters[2])
  Sigma_Log <- as.numeric(KM_log$parameters[2])
  VAR <- Sigma^2
  VAR_Log <- Sigma_Log^2
  Median <- median(WELL_SUB$MEAN_REPORTED)
  Median_log <- median(log(WELL_SUB$MEAN_REPORTED))
  MaxDate <- max(WELL_SUB$EVENT,na.rm=TRUE)

 }
 #------------------------------------------------------------------------#

 #------------------------------------------------------------------------#
```

```
  #--Calculate Statistics for Pooled Variance--#
  if (ANALYTES[i] == 'pH Measurement'){
   S_SUB <- data.table(Well_Name=WELLS[k],
                N=N,
                MEAN=MEAN,
                SD=Sigma,
                VAR=VAR)
  } else {
   S_SUB <- data.table(Well_Name=WELLS[k],
                N=N,
                MEAN=MEAN_Log,
                SD=Sigma_Log,
                VAR=VAR_Log)
  }
  SD <- rbind(SD,S_SUB)
  #-----------------------------------------------------------------------#

  #-----------------------------------------------------------------------#
  #--Calculate Summary Statistics--#
  STATS_SUB <- data.table(RCRA_Site = SITES[j],
                Well_Name = WELLS[k],
                ANALYTE = ANALYTES[i],
                MEAN = MEAN,
                VAR = VAR,
                SD = Sigma,
                MEAN_Log = MEAN_Log,
                VAR_Log = VAR_Log,
                SD_Log = Sigma_Log,
                N = length(WELL_SUB$MEAN_REPORTED),
                PNDS=mean(WELL_SUB$NDS),
                MAX=max(WELL_SUB$MEAN_REPORTED,na.rm=TRUE),
                Median=Median,
                Max.date=MaxDate)
  STATS <- rbind(STATS,STATS_SUB)
  #-----------------------------------------------------------------------#

 }
 #-----------------------------------------------------------------------#

}
#-----------------------------------------------------------------------#

#-----------------------------------------------------------------------#
#--Pooled Variance--#
if(SITES[j] == 'LLWMA-2' & ANALYTES[i] %in% c('pH Measurement') |
  SITES[j] == 'LLWMA-3' & ANALYTES[i] %in% c('pH Measurement','Specific Conductance')){

 SD$VAR2 <- (SD$N-1)*SD$VAR
 VAR_POOLED <- sum(SD$VAR2,na.rm=TRUE)/(nrow(ANALYTE_SUB)-length(unique(ANALYTE_SUB$Well_Name)))
 SD_POOLED <- sqrt(VAR_POOLED)
 N_POOLED <- length(ANALYTE_SUB$MEAN_REPORTED)
 DF_POOLED <- N_POOLED-length(unique(ANALYTE_SUB$Well_Name))

}
#-----------------------------------------------------------------------#

#-----------------------------------------------------------------------#
#--Summary Statistics--#
if(SITES[j] == 'LLWMA-2' & ANALYTES[i] %in% c('pH Measurement') |
  SITES[j] == 'LLWMA-3' & ANALYTES[i] %in% c('pH Measurement','Specific Conductance')){

 STATS$POOLED_SD <- SD_POOLED
 STATS$POOLED_N <- N_POOLED
 STATS$ALPHA <- 0.01
 STATS$DF_POOLED <- DF_POOLED
 if(ANALYTES[i] == 'pH Measurement'){
  STATS$TCRIT <- qt(1-STATS$ALPHA/2,df=DF_POOLED)
 } else {
  STATS$TCRIT <- qt(1-STATS$ALPHA,df=DF_POOLED)
 }
```

```
    } else {

    STATS$POOLED_SD <- NA
    STATS$POOLED_N <- NA
    STATS$ALPHA <- 0.01
    STATS$DF_POOLED <- NA

  }
  #----------------------------------------------------------------------------#

  #----------------------------------------------------------------------------#
  #--Calculate Critical Means--#
  if(SITES[j] == 'LLWMA-2' & ANALYTES[i] %in% c('pH Measurement') |
    SITES[j] == 'LLWMA-3' & ANALYTES[i] %in% c('pH Measurement','Specific Conductance')){

    if (ANALYTES[i] == 'pH Measurement'){

      STATS$CMUP_LOG <- NA
      STATS$CMDW_LOG <- NA
      STATS$CMUP <- STATS$MEAN + STATS$TCRIT * STATS$POOLED_SD * sqrt(1 + 1/STATS$POOLED_N)
      STATS$CMDW <- STATS$MEAN - STATS$TCRIT * STATS$POOLED_SD * sqrt(1 + 1/STATS$POOLED_N)

    } else {

      STATS$CMUP_LOG <- STATS$MEAN_Log + STATS$TCRIT * STATS$POOLED_SD * sqrt(1 + 1/STATS$POOLED_N)
      STATS$CMDW_LOG <- NA
      STATS$CMUP <- exp(STATS$CMUP_LOG)
      STATS$CMDW <- exp(STATS$CMDW_LOG)

    }

  } else {

    if(ANALYTES[i] == 'pH Measurement'){
      ALPHA_CRIT <- 0.01/2
    }      else {
      ALPHA_CRIT <- 0.01
    }

    STATS$TCRIT <- qt(ALPHA_CRIT,df=STATS$N-1,lower.tail=FALSE,log=FALSE)
    STATS$CMUP_LOG <- NA
    STATS$CMDW_LOG <- NA
    STATS$CMUP <- STATS$MEAN + STATS$TCRIT *STATS$SD * sqrt(1 + 1/STATS$N)
    STATS$CMDW <- STATS$MEAN - STATS$TCRIT *STATS$SD * sqrt(1 + 1/STATS$N)

  }
  OUT <- rbind(OUT,STATS)
  #----------------------------------------------------------------------------#

 }
 #----------------------------------------------------------------------------#

}
#----------------------------------------------------------------------------#

#----------------------------------------------------------------------------#
#--Export output matrix--#
FILE <- paste0('Output/Runs - 1-13-2020/HANFORD-CRITICAL_MEANS-INTRAWELL_2019_',as.character(Sys.Date()),'.csv')
write.table(OUT,FILE, sep = ",", row.names = FALSE)
save(OUT,file='Output/Runs - 1-13-2020/IntrawellTest_CMs.Rdata')
save(DATA_SUM,file='Output/Runs - 1-13-2020/IntrawellTest_SummedData.RData')
#----------------------------------------------------------------------------#

#----------------------------------------------------------------------------#
#--This script calculates the Critical Means for Hanford RCRA Areas for CY2020
#--Interwell Method
#--Script written by: E. DiFilippo (SSP&A): modified from ECF-HANFORD-13-0013, REV. 0
#--R Version: 3.3.2
```

```
#--Package data.table version: 1.10.4.2
#--Package EnvStats version: 2.3.0
#--Package outliers version: 0.14
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Set working directory--#
DIR <- 'Z:/1639_HANFORD_FY2020/66007-43 RCRA Regulatory Support and Data Evaluation_Reduction/Critical Means'
setwd(DIR)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Load Libraries--#
library(data.table)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Import Datasets--#
load('Data/Runs - 1-13-2020/Interwell.RData')
load('Data/Runs - 1-13-2020/Intrawell.RData')
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Remove Obsolete Sites--#
rmsites <- subset(INTER$INTERSITES,INTER$INTERSITES$RCRA_Site %in% c('116-N-1 (1301-N)','116-N-3 (1325-N)'))
INTER$DATA <- INTER$DATA[!NAME %in% rmsites$Well_Name]
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Combine All Datasets--#
DATA <- rbind(INTER$DATA,INTRA$DATA)
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Summary of Total Number of Samples--#
TOTALS <- data.table(ROWS=c('Total No. Samples',
                'Total No. pH Samples',
                'Total No. SC Samples',
                'Total No. TOC Samples',
                'Total No. TOX Samples'),
            TOTALS=c(nrow(DATA),
                nrow(DATA[ANALYTE=='pH Measurement']),
                nrow(DATA[ANALYTE=='Specific Conductance']),
                nrow(DATA[ANALYTE=='Total organic carbon']),
                nrow(DATA[ANALYTE=='Total organic halides'])),
            PERCENT=c(100,
                (nrow(DATA[ANALYTE=='pH Measurement'])/nrow(DATA)),
                (nrow(DATA[ANALYTE=='Specific Conductance'])/nrow(DATA)),
                (nrow(DATA[ANALYTE=='Total organic carbon'])/nrow(DATA)),
                (nrow(DATA[ANALYTE=='Total organic halides'])/nrow(DATA))))
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Extract Upgradient Wells--#
UP <- sort(unique(c(subset(INTER$INTERSITES,INTER$INTERSITES$Loc == 'UP')$Well_Name,
        subset(INTRA$INTRASITES,INTRA$INTRASITES$Loc == 'UP')$Well_Name)))
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Subset Dataset for Upgradient Wells--#
DATA_UP <- DATA[NAME %in% UP]
#------------------------------------------------------------------------#


#------------------------------------------------------------------------#
#--Summary of Total Number of Samples for Upgradient Wells--#
T2 <- data.table(ROWS=c('Total No. Samples',
                'Total No. pH Samples',
                'Total No. SC Samples',
                'Total No. TOC Samples',
                'Total No. TOX Samples'),
```

```
            TOTALS=c(nrow(DATA_UP),
                  nrow(DATA_UP[ANALYTE=='pH Measurement']),
                  nrow(DATA_UP[ANALYTE=='Specific Conductance']),
                  nrow(DATA_UP[ANALYTE=='Total organic carbon']),
                  nrow(DATA_UP[ANALYTE=='Total organic halides'])),
            PERCENT=c(100,
                  (nrow(DATA_UP[ANALYTE=='pH Measurement'])/nrow(DATA_UP)),
                  (nrow(DATA_UP[ANALYTE=='Specific Conductance'])/nrow(DATA_UP)),
                  (nrow(DATA_UP[ANALYTE=='Total organic carbon'])/nrow(DATA_UP)),
                  (nrow(DATA_UP[ANALYTE=='Total organic halides'])/nrow(DATA_UP))))
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Remove Data Based on Review Qualifier--#
REMOVED <- DATA_UP[REVIEW_RM == TRUE]
DATA_R <- DATA_UP[REVIEW_RM == FALSE]
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Summary of Total Number of Samples Removed based on Review Qualifier--#
T3 <- data.table(ROWS=c('Total No. Samples',
                  'Total No. pH Samples',
                  'Total No. SC Samples',
                  'Total No. TOC Samples',
                  'Total No. TOX Samples'),
            T_RM=c(nrow(REMOVED),
                  nrow(REMOVED[ANALYTE=='pH Measurement']),
                  nrow(REMOVED[ANALYTE=='Specific Conductance']),
                  nrow(REMOVED[ANALYTE=='Total organic carbon']),
                  nrow(REMOVED[ANALYTE=='Total organic halides'])))
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Calculate Percent of Total Removed - Review Qualifier--#
setkey(T2,ROWS)
setkey(T3,ROWS)
T3 <- T2[T3]

T3$PERCENT <- (T3$T_RM/T3$TOTALS)
T3 <- subset(T3,select=c('ROWS','T_RM','PERCENT'))
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Remove Data Based on Review Qualifier--#
REMOVED_C <- DATA_UP[COLLECT_RM == TRUE]
DATA_C <- DATA_R[COLLECT_RM == FALSE]
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Summary of Total Number of Samples Removed based on Collection Purpose--#
T4 <- data.table(ROWS=c('Total No. Samples',
                  'Total No. pH Samples',
                  'Total No. SC Samples',
                  'Total No. TOC Samples',
                  'Total No. TOX Samples'),
            T_CP=c(nrow(REMOVED_C),
                  nrow(REMOVED_C[ANALYTE=='pH Measurement']),
                  nrow(REMOVED_C[ANALYTE=='Specific Conductance']),
                  nrow(REMOVED_C[ANALYTE=='Total organic carbon']),
                  nrow(REMOVED_C[ANALYTE=='Total organic halides'])))
#----------------------------------------------------------------------#


#----------------------------------------------------------------------#
#--Calculate Percent of Total Removed - Collection Purpose--#
setkey(T2,ROWS)
setkey(T4,ROWS)
T4 <- T2[T4]

T4$PERCENT <- (T4$T_CP/T4$TOTALS)
T4 <- subset(T4,select=c('ROWS','T_CP','PERCENT'))
```

```
#----------------------------------------------------------------------#

#----------------------------------------------------------------------#
#--Summary of Total Number of Aliquots--#
T5 <- data.table(ROWS='Total No. Samples',
         TOTALS=nrow(DATA_C))

T5$PERCENT <- (T5$TOTALS/T2[ROWS=='Total No. Samples']$TOTALS)
#----------------------------------------------------------------------#

#----------------------------------------------------------------------#
#--Summary of Total Number of Non-Detects--#
NDS_TOT <- DATA_C[NDS==TRUE]
T6 <- data.table(ROWS=c('Total No. Samples',
                 'Total No. pH Samples',
                 'Total No. SC Samples',
                 'Total No. TOC Samples',
                 'Total No. TOX Samples'),
           T_ND=c(nrow(NDS_TOT),
                 nrow(NDS_TOT[ANALYTE=='pH Measurement']),
                 nrow(NDS_TOT[ANALYTE=='Specific Conductance']),
                 nrow(NDS_TOT[ANALYTE=='Total organic carbon']),
                 nrow(NDS_TOT[ANALYTE=='Total organic halides'])))
#----------------------------------------------------------------------#

#----------------------------------------------------------------------#
#--Calculate Percent of Non-Detects--#
setkey(T2,ROWS)
setkey(T6,ROWS)
T6 <- T2[T6]

T6$PERCENT <- (T6$T_ND/T6$TOTALS)
T6 <- subset(T6,select=c('ROWS','T_ND','PERCENT'))
#----------------------------------------------------------------------#

#----------------------------------------------------------------------#
#--Calculating Summary Statistics for each Well by Sample Date
DATA_SUM <- data.table(DATA_C)[,list(N_NDS=sum(NDS),
                 N_SAMPLE=length(NDS),
                 PROPND=sum(NDS)/length(NDS),
                 MEAN_REPORTED=mean(VAL),
                 DETLIMIT=min(VAL),
                 MEAN_DETECTS=mean(VAL[!NDS]),
                 SD_DETECTS=sd(VAL[!NDS]),
                 CV_DETECTS=sd(VAL[!NDS])/mean(VAL[!NDS])),
             by=c("NAME","EVENT","ANALYTE")]
#----------------------------------------------------------------------#

#----------------------------------------------------------------------#
#--Summary of Total Number of Composite Samples--#
T7 <- data.table(ROWS=c('Total No. Samples',
                 'Total No. pH Samples',
                 'Total No. SC Samples',
                 'Total No. TOC Samples',
                 'Total No. TOX Samples'),
           T_COMP=c(nrow(DATA_SUM),
                 nrow(DATA_SUM[ANALYTE=='pH Measurement']),
                 nrow(DATA_SUM[ANALYTE=='Specific Conductance']),
                 nrow(DATA_SUM[ANALYTE=='Total organic carbon']),
                 nrow(DATA_SUM[ANALYTE=='Total organic halides'])))
#----------------------------------------------------------------------#

#----------------------------------------------------------------------#
#--Calculate Percent of Total--#
setkey(T2,ROWS)
setkey(T7,ROWS)
T7 <- T2[T7]

T7$PERCENT <- (T7$T_COMP/T7$TOTALS)
T7 <- subset(T7,select=c('ROWS','T_COMP','PERCENT'))
```

```
#----------------------------------------------------------------------------#

#----------------------------------------------------------------------------#
#--Export Data Summaries--#
write.table(TOTALS,paste0('Output/Runs - 1-13-2020/Summary
Tables/DataSummary_AllHEISSamples_',as.character(Sys.Date()),'.csv'),sep=',',row.names=FALSE)
write.table(T2,paste0('Output/Runs - 1-13-2020/Summary
Tables/DataSummary_AllUpgradient_',as.character(Sys.Date()),'.csv'),sep=',',row.names=FALSE)
write.table(T3,paste0('Output/Runs - 1-13-2020/Summary
Tables/Totals_Removed_Qualifier_',as.character(Sys.Date()),'.csv'),sep=',',row.names=FALSE)
write.table(T4,paste0('Output/Runs - 1-13-2020/Summary
Tables/Totals_Removed_Collection_',as.character(Sys.Date()),'.csv'),sep=',',row.names=FALSE)
write.table(T5,paste0('Output/Runs - 1-13-2020/Summary Tables/Totals_Aliquots_',as.character(Sys.Date()),'.csv'),sep=',',row.names=FALSE)
write.table(T7,paste0('Output/Runs - 1-13-2020/Summary Tables/Totals_Composite_',as.character(Sys.Date()),'.csv'),sep=',',row.names=FALSE)
write.table(T6,paste0('Output/Runs - 1-13-2020/Summary Tables/Totals_NDs_',as.character(Sys.Date()),'.csv'),sep=',',row.names=FALSE)
#----------------------------------------------------------------------------#
```